

THE CAMBRIAN FAUNAS OF NORTH-EASTERN AUSTRALIA.

Part 1: STRATIGRAPHICAL OUTLINE.

Part 2: TRILOBITA (MIOMERA).

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Plates VIII-X. Text-figures 1-4.

Part 1. STRATIGRAPHICAL OUTLINE.

(a) EXPLANATION.

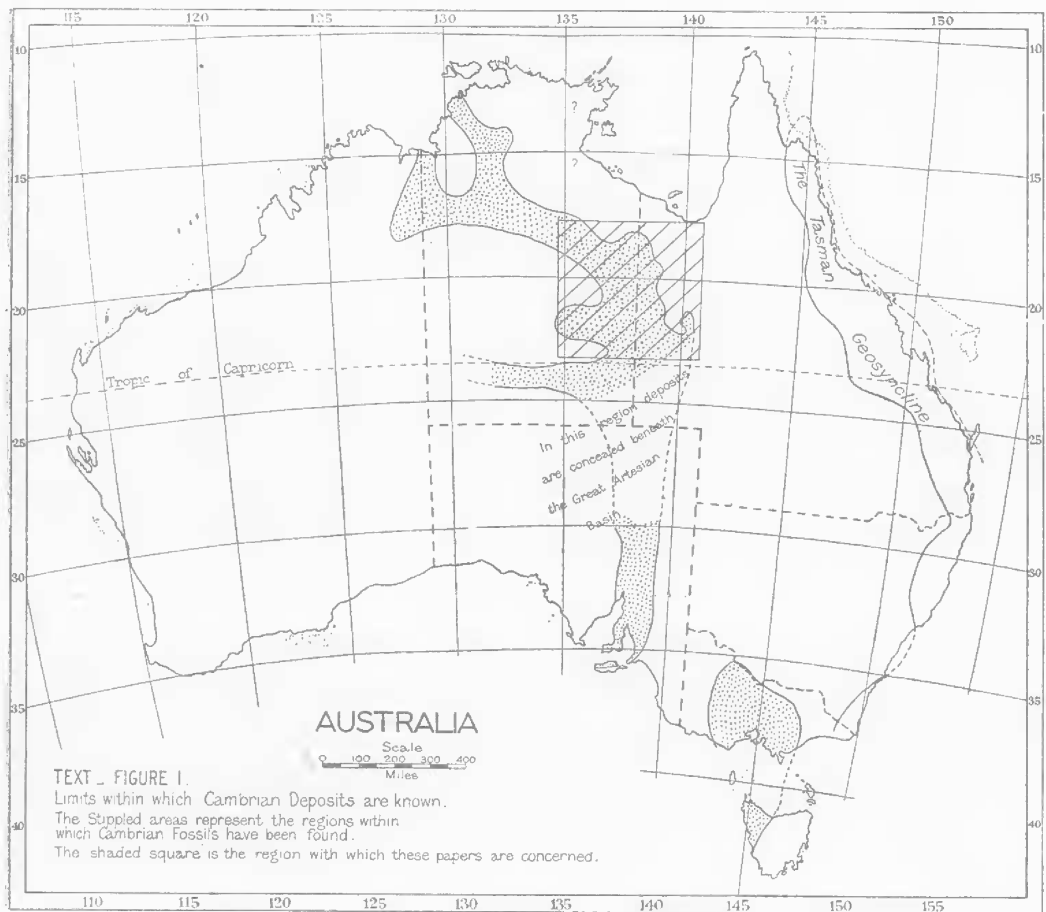
The Cambrian rocks of Australia lie in two large linear basins, and an outlying province in Victoria and Tasmania (text-figure 1). In the east of the continent, stretching along almost the whole of the coastal belt, is the Tasman Geosyncline, one of the greatest yet one of the least studied geosynclines of the globe. The uppermost beds, that range from Devonian to Permian in age, are richly fossiliferous. Below them is a colossal thickness of sediments from which few fossils are known. In the Brisbane region Denmead (1928, pp. 79, 83, 89 and 95) has estimated that this pre-Devonian portion of the section is not less than 75,000 feet thick. Some portion of these older beds must be of Cambrian age, but no Cambrian fossils have been recorded.

The other group of which more is known is a great, arcuate belt of sediments and volcanic rocks stretching from the Kimberley District of Western Australia to Adelaide and beyond in South Australia. Where Queensland, South Australia and the Northern Territory join, the outcrop of this belt is interrupted by later (Cretaceous) beds of the Great Artesian Basin. An east-west extension from the Cambrian beds runs through the Macdonnell Ranges, giving to the whole belt the shape of a reversed F.

In South Australia and in the Macdonnell Ranges the rocks of this belt are highly folded. But in the northern and larger portion the beds are little disturbed. Generally they are horizontal; and they are so little changed that on several occasions they have been mistaken for Tertiary sediments. In this series of papers the faunas of the north-eastern portion of the province,¹ in western Queensland and the adjacent

¹ It has been difficult to select a succinct but adequate title for these papers. The term "north-eastern Australia" is not particularly satisfactory. Actually the area concerned is the region adjacent to and on both sides of the boundary between Queensland and the Northern Territory.

portions of the Northern Territory, will be described. Here with few exceptions the beds lie flatly, often perfectly so, and mapping of horizons is thus on a grand scale. Direct proof of succession of beds more often than not is wanting; but from this region a series of index faunas has been found ranging from the top of the Lower to near the top of the Upper Cambrian. Provisionally it would seem that there is a conformable sequence of beds covering this greater part of the period.



(b) PREVIOUS RECORDS OF CAMBRIAN FAUNAS.

The geographical limits of the area with which I am concerned in these papers may be seen on the map that is text-figure 2. Here Cambrian beds cover an area of between 50,000 and 60,000 square miles, although a widespread development of loosely consolidated and relatively recent sediments (? Pleistocene) masks the full extent of the older beds. The records in literature of Cambrian rocks and fossils in this region are surprisingly few.

Cambrian fossils were first found in 1894 when H. Y. L. Brown, who then was Government Geologist of South Australia, obtained a trilobite from the spoil heap of a well five miles to the north of Alexandria Downs homestead in the Northern Territory. Brown placed this on record in the following year.² In 1897 the fossil was described by R. Etheridge Jr. as *Olenellus browni*.

In 1902 Etheridge described two more trilobites from the eastern part of the Northern Territory. These, which he named *Agnostus elkedraensis* and *Microdiscus significans*, had been found by A. A. Davidson in 1898 at a locality forty miles south east of Elkedra.³

The next record is in the year 1915 when Dr. H. I. Jensen (1915, pl. 4, figs. 2, 3), making no comment, figured a trilobite that had been obtained by A. L. Merrotsky eight miles east of Alroy Downs. This species was described by Etheridge in 1919 as a new species, *Ptychoparia alroiensis* (p. 385, pl. 40, fig. 8). It was unfortunate that three years later J. Mitchell (1922, p. 539, pl. 54, figs. 11, 12) gave the name *Ptychoparia merrotskii* sp. nov. using the same specimen as holotype.

In 1919 Etheridge summarised our knowledge of the Cambrian trilobites of Australia and discussed the affinities of all species known at that time.

Brown, in 1895, had commented on the widespread distribution in the Northern Territory of limestones similar to those from which the few Cambrian fossils had been found, and suggested that these beds were Cambrian. But the area is so sparsely settled that discoveries came slowly. A decade elapsed between the time of Merrotsky's discovery and the next find of Cambrian fossils. This was in 1924 when E. C. Saint-Smith placed on record the first Cambrian fossils found in Queensland. These were obtained by J. C. Miles on the Templeton River. The specimens had been referred to W. Dun for advice, and Saint-Smith in his notice quoted Dun's provisional determinations of the genera *Olenellus*, *Ptychoparia* and *Micromitra*. Dun suggested a Lower Cambrian age for the beds which Saint-Smith stated were intruded by the granites that are injected through the Pre-Cambrian.⁴

In 1927 I recorded from the same beds of the Templeton River *Eodiscus significans* (Eth. fil.), *Agnostus elkedraensis* Eth. fil. and species of *Dinesus* and *Notasaphus* (?) suggesting a Middle Cambrian age for the beds.

Two years later, in 1929, Chapman described a suite of fossils from the beds of the Templeton and Thornton Rivers. His list of determinations is as follows: *Lingulella marcia* Walcott var. *templetonensis* C., *Acrothele bulboides* C., *Agnostus*

² The references to these works will be found in the bibliography at the end of this paper, listed under the name of the author and the year of publication.

³ This has been recorded by Davidson (1905) p. 6.

⁴ I cannot verify the latter observation. The Templeton Series in this area appears to rest on the eroded surface of the granite.

chinensis Dames, *Bathyriscus saint-smithi* C., *B. nitidus* C., *B. olenelloides* C., *Marjumi* *milesi* C., *M. conspicabilis* C., *M. elegans* C., *Dikelocephalus dunstani* C. and *Milesia templetonensis* C. Chapman regarded the beds to be "of Middle to Upper Cambrian age."

In 1930 I gave the name Templeton Series to these beds and recorded a lower horizon with *Redlichia*.

During the following year came the biggest advance in the collection of Cambrian faunas. Mr. B. Dunstan made valuable collections that are now the property of the Geological Survey of Queensland. Mr. C. Ogilvie recognised the importance of the widespread series for which he suggested the name Georgina Limestone. He searched for and found fossils in a number of localities in these beds. Following upon this, in 1931, I recognised the following faunal stages in the collections :—

- (i.) A *Pagodia* Stage (upper part of the Upper Cambrian) with *Pagodia* (?), *Hyolithes*, *Eoorthis*, *Acrotreta* and *Lingulella*.
- (ii.) A *Proceratopyge* Stage (lower part of the Upper Cambrian) with *Proceratopyge*, *Agnostus*, *Ptychagnostus*, *Pseudagnostus* and *Lingulella*.
- (iii.) A *Leiagnostus* Stage (upper part of the Middle Cambrian) with *Agnostus*, *Leiagnostus*, *Obolus* and *Acrotreta*.
- (iv.) A *Dinesus* Stage (lower part of the Middle Cambrian) with Chapman's fauna and the genera *Pagetia*, *Dinesus*, *Notasaphus* and *Paradoxides* (?).
- (v.) A *Redlichia* Stage (upper part of the Lower Cambrian) with *Redlichia* and *Leperditia*.

These details were incorporated by David in 1932 in his summary of the Cambrian of Australia.

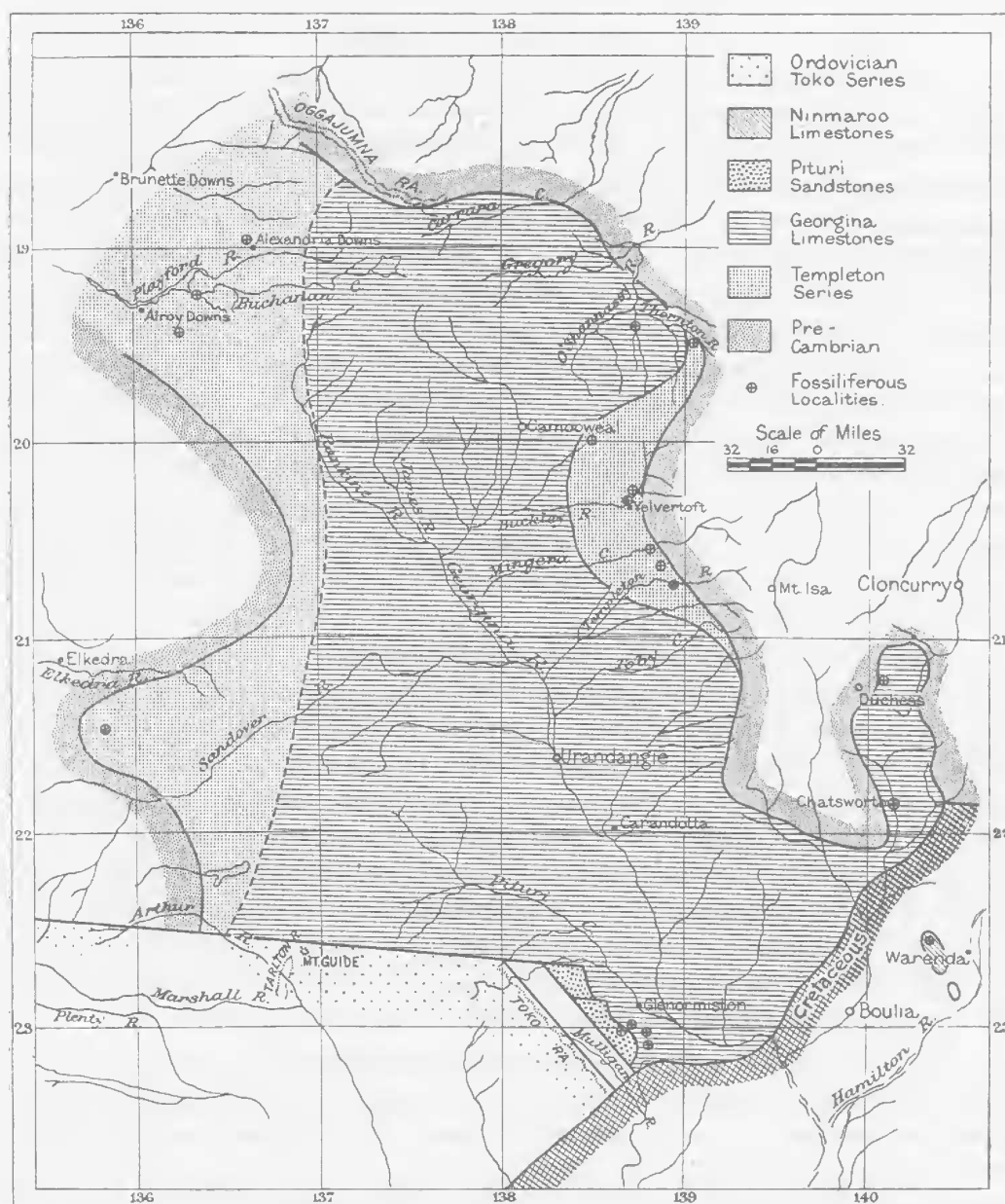
In 1931 Anderson published a photograph of a trilobite from the Templeton River⁵; and in 1935 Fletcher reproduced the same picture and gave some notes on the occurrence of the trilobite beds of the Templeton and Thornton Rivers.

The latest reference is by Kobayashi (1935b) who described and figured a trilobite from the Templeton River as *Dinesus ida* Eth. fil.

At intervals in the past four years I have been working in this field. Field work is difficult. The area is enormous, it is remote from the larger towns, and outcrops are spasmodic. Some of the region is desert land and is unoccupied. Even the best of the country is sparsely settled. On the Queensland side the area of each of the pastoral holdings is of the order of 3,000 square miles. In the Northern Territory the holdings are much larger, reaching as much as 13,000 square miles with Alexandria Downs. In addition to this I have been able to carry on the work only in the summer,

⁵ *Xystridura saint-smithi* (Chapman).

a trying time when floods from the monsoonal rains in the north frequently hold up traffic and communications. Because of these things the field investigations are most incomplete. I had hoped to withhold publication of the palaeontological results until



Text-figure 2.—An interpretation of the Geology of the Georgina Basin. Deposits later in age than Cretaceous are omitted.

considerably more data were available. But field progress is slow and the palaeontological determinations already obtained have potential value for the correlation of other Australian areas, so that a series of papers, of which this is the first, has been prepared describing the faunas.

(c) STRATIGRAPHICAL DETAILS.

The basins of the Georgina River and most of its main tributaries lie in a great tongue of limestones with a general north-south elongation. To these beds the name Georgina Limestones has been given (Whitehouse 1931). The fossiliferous stages that are present show that the beds range from at least the *Phoidagnostus* Stage (equivalent to the *Paradoxides davidis* Zone of the Middle Cambrian) to the *Glyptagnostus* Stage (equivalent to the *Olenus* Zone of the Upper Cambrian). Conformably above them and representing other horizons of the Upper Cambrian are the Pituri Sandstones. On either side of the belt of the Georgina Limestones are beds with earlier faunas, ranging downwards to the *Redlichia* Stage at the top of the Lower Cambrian. In the east this lower group occurs in a circumscribed area in the basins of the Templeton, Thornton, Mingera and Buckley waters. These beds have been called the Templeton Series (Whitehouse 1930).⁶ In the west outcrops are rare. That being so it would be premature to give to this group a separate series name. For the moment all such earlier beds are included under the name Templeton Series, and the two groups will be referred to as the eastern and the western developments of the Series.

The eastern development of the Templeton Series is entirely non-calcareous. The dominant rock types are sandstones, siltstones, cherts (many of which seem to be original siliceous deposits, not later replacements) and white to biscuit-coloured siliceous shales. These rocks, everywhere that I have seen them, are horizontal or nearly so. Unfortunately not far away, on the Great Artesian Basin, lacustrine Tertiary beds have much the same lithology in their sandstone and shale members. Therefore in the region with which I am concerned, where Tertiary beds may be and most probably are present and where outcrops are intermittent, sometimes it has been impossible to determine whether non-fossiliferous beds are Cambrian or Tertiary in age. It follows that it is not possible at present to state precisely how extensive are the beds of the Templeton Series. Neither is their thickness known.

On Yelvertoft Station the lowest beds, with *Redlichia*, may be seen resting on tilted Pre-Cambrian quartzites. Further to the south-east later beds with *Dinesus* occur and continue to the margin of the basin. On the divide between Mingera

⁶ Bryan (1928, p. 58) has attributed the name Templeton Series to Dunstan. At the time when Bryan's work appeared the Geological Survey of Queensland, under Mr. B. Dunstan, anticipated publishing a new geological map of Queensland on which the name Templeton Series would be used for the Cambrian beds west of Mount Isa. This map was not published.

Creek and the Templeton River these beds rest on Pre-Cambrian granites and quartzites, so that apparently there is a considerable overlap of the *Dinesus* beds in this region. It may be mentioned that in their eastern limits, in the valley of the Templeton River, the *Dinesus* beds appear locally to be thrust over the Pre-Cambrian quartzites.

In its western development the Templeton Series rarely is seen outcropping. Usually fossils have been obtained from wells or from the silt-encrusted beds of the creeks. White and biscuit-coloured shales, identical with the matrix of the *Dinesus* beds in the east, are found with the same fossils. Unlike the eastern development the Templeton Series here contains limestones.

Although four faunal stages have been recognised in the Templeton Series only one of them, the *Dinesus* Stage, has been found widespread. The other three horizons are known at present each from but a single locality—the *Redlichia* Stage from Yelvertoft homestead, the *Amphoton* Stage from Split Rock on Waroona Creek, and the *Inouyella* Stage from No. 4 well on Alroy Downs.

Over an enormous part of the area in which they are developed the Georgina Limestones seem to be perfectly horizontal. The plateau nature of the Barkly Tableland, where they occur, in part may be due to this. Consequently, and due also to the deep pedocalcic soils of the region and the widespread development of late (? Pleistocene) deposits, outcrops are infrequent. Away from the Barkly Tableland, in the basins of the Thornton, Seymour and O'Shanassy Rivers, and also in the lower reaches of the Georgina, outcrops are more common. In these regions dips of varying degrees often are to be detected in the beds; and no doubt it is due to this that outcrops are better. Generally such dips are small; but in the north-east, near the junction with the Pre-Cambrian, dips up to 20° are seen commonly, while at two localities on Glenormiston in the south, along fault zones, there are dips of 60° .

In its northerly development towards the Oggajumna Ranges and also in the east (except in the region of the Templeton-Mingera-Buckley Basins) the Georgina Limestones rest upon the Pre-Cambrian complex. Such marginal junctions may be seen, for example, east of Duchess and also in the unnamed ranges in the basin of the O'Shanassy River where long ago Jack (1885, p. 9) recorded an unconformity between the Pre-Cambrian sandstones and the limestones. Furthermore Pre-Cambrian inliers occur in the limestones at a number of places, for instance on Glenormiston and Carandotta. From this it is suggested that, except in the Templeton-Mingera-Buckley area, the Georgina Limestones are transgressive across the Templeton Series on to the Pre-Cambrian. Nevertheless from the faunal analysis it would seem that, in spite of this transgression and the abrupt lithological change, there is little

possibility of a time break in the passage from the Templeton Series to the Georgina Limestones.⁷ The relatively high dip of the limestones near their junction with the Pre-Cambrian in the Thornton River basin suggests some localised, marginal faulting.

There is a considerable variation in the limestone types in this series. White, cream and brown finely crystalline limestones are common. More closely grained types also are abundant, particularly a bluish type that has a very smooth texture. Such blue limestones are thick in the upper part of the section, in the beds with the *Proceratopyge* faunas. The texture of these rocks is so fine and the jointing so close that almost all the wells and bores sunk in them for water on Glenormiston Station have proved to be failures. Tyson's Bore, a failure on that property, penetrated limestones to its total depth of 1,810 feet; and tentatively this may be taken as a minimum thickness for these blue limestones in the upper part of the Series.

Just as, in the non-calcareous beds of the Templeton Series, difficulties in mapping have been caused by the similarity to adjacent shales and sandstones of Tertiary age, so in the region of the Georgina Limestones there are other hard, horizontal limestones of apparently Pleistocene age that are so similar to the Cambrian beds that mapping becomes difficult.⁸ These later beds have been recorded in the north (Ball 1911, p. 17), but they are abundant also in the south (e.g. in the basin of Pituri Creek) as well as beyond the limit of outcrop of the Cambrian beds (on Warenda and Roseberth).

Within this region of the Georgina Limestones there are vast areas where the pedocalcic soils become so deep that the surface is a soil plain devoid of rocky outcrops. This is shown extremely in the south of the region in the area west of the border fence. Here the soil is so fine grained and non-cohesive in the dry weather that locally it goes by the name of "Bull Dust."⁹ The extensive view northwards over these Bull Dust Plains from the northern scarp of the Tarlton Range is one of the most monotonously level prospects that I have seen.

⁷ An alternative explanation, but one that I do not favour, is that away from the type region the sediments of the Templeton Series grade laterally into the lower members of the Georgina Limestones. For the purpose of these papers it will be assumed that the Georgina Limestones are consistently later than the *Dinesus* beds.

⁸ Several sections have shown that these beds are later than the lateritic soils of this region. It is interesting to note that on two occasions before the discovery of Cambrian fossils in Queensland, these western beds were mapped as late formations. Cameron in 1901, after Post-Tertiary gastropods had been found in the later limestones, mapped all the limestones of the Barkly Tableland as Post-Tertiary. Dunstan in 1920 mapped the whole of the Cambrian of Western Queensland as Jurassic. In 1872 Daintree, recording the presence of *Tellina*, suggested that the age of the limestones of the Barkly Tableland was Cretaceous. The confused nature of the evidence even as long ago as 1895, puzzled R. L. Jack.

⁹ This soil is not confined to the Cambrian Limestones. South east of Birdsville, for example, it occurs on the Tertiary rocks capping the great Artesian Basin.

The thickness of the Georgina Limestones I am not yet able to determine, nor am I prepared at present to give a sequence of the various limestone types in the Series.

A feature of some importance is the presence of cherts in the sequence. Some of these are replaced limestones. Part at least of this replacement has taken place in late Tertiary or Post-Tertiary times; for the relatively recent limestones also are affected, usually more completely than the Cambrian beds. But in addition to such secondary replacements there are cherts of primary deposition, occurring as peculiar, sausage-like masses along bedding planes, and as thin beds with curious, incised but superficial, concentric rings suggesting that they have been formed by the deposition of colloidal silica giving Liesegang structures. Such deposits are common also in the beds of the Templeton Series (text-fig. 3).



Text-figure 3.—Liesegang-like structures in Cambrian cherts from the Thornton River. ($\times \frac{2}{3}$).

From the basal beds of the Georgina Limestones I have not yet obtained fossils. The earliest faunas come from areas east of Camooweal and east and south east of Duchess. These belong to the upper part of the Middle Cambrian. Several faunal stages have been recognised with *Phoidagnostus* and *Anomocare*. Other fossiliferous stages occur a considerable distance to the south in beds at the top of the series. These have yielded faunas with *Proceratopyge* and *Pseudagnostus* that belong to the lower part of the Upper Cambrian. Curiously enough, although these

two fossiliferous regions are so far apart and have no faunal stages in common, there does not seem to be any chronological gap between the known stages of this part of the Queensland Cambrian.

In the western part of Glenormiston Station (which is in the southernmost part of the province) the blue limestones with *Proceratopyge* conformably are overlain by a series of sandstones and some siliceous shales to which the name Pituri Sandstones¹⁰ is now given. Here the beds become horizontal in the southern part of their outcrop, a region of desolate, unoccupied sandstone country that sometimes gives rise to table-topped hills and sometimes is covered by the big, red sandhills of the desert. A little further north, in the basin of Wheelaman Creek, the sandstones have been faulted in a somewhat puzzling way, and there the beds have perceptible dips to the west.

The Pituri Sandstones have a minimum thickness of 100 feet. Fossils have been found only at one place in the Series—immediately west of Tyson's Bore on Glenormiston, in beds near the base of the sandstones. These have yielded the *Elathriella* fauna. One member of this is *Pseudagnostus*, a genus common to the upper stages of the Georgina Limestones, so that it would seem, in spite of the abrupt lithological change, that there has been no time break during this passage.

Further west no other Cambrian beds are known. Instead there are Ordovician beds, the Toko Series,¹¹ that begin with a rich cephalopod limestone containing *Actinoceras*, *Deiropoceras*, *Calhounoceras*, "*Endoceras*," *Vaginoceras*, and several new genera allied to *Kochoceras*, *Armenoceras* and other boreal forms. Above these lie horizontal sandstones with asaphid trilobites. This appears to be a Middle Ordovician group, the cephalopod limestone being the equivalent of the Black River Stage in America.

Thus in this region no beds of Ozarkian (Tremadocian) or Lower Ordovician (Canadian) age have been found. From the straight line relationships with the Ordovician it would appear that it is a faulted junction,¹² the fault striking 320° E. of

¹⁰ The aborigines of the Idamea and Toko tribes that inhabited Glenormiston Station did considerable trading with other tribes in the relatively rare plant, *Duboisia Hopwoodii* (von Mueller), the native name for which is Pituri. The plant was valued for its narcotic properties, due to the alkaloid Duboisine. Pituri Creek is named after this plant, although it is not known to have grown in the basin of this waterway. The plant, now very scarce in Western Queensland, was once common in the south of Glenormiston and in the basin of the Mulligan River. Part of these sandstones lie in this region; and in the absence of appropriate place names (the aboriginal names are very long) I have selected the name Pituri Sandstones for the Series.

¹¹ I propose this term to replace "Glenormiston Series" (Whitehouse 1930), since, although the series occurs on Glenormiston, the greater part of that property is occupied by Cambrian beds.

¹² No contact is visible. In front of the scarp of the Toko Range there is a long, alluvium-filled valley worn out along the junction. For reasons that it is hardly appropriate to discuss in this paper I believe that there is a trough fault along the junction.

N. But the gap is bridged to some extent by deposits further to the east, in a series of inliers in the Cretaceous. On Warenda Station east of Boulia there are three large hills—Black Mountain (Unbunmaroo), Ninmaroo and Mt. Datson. These consist of folded limestones of considerable thickness and identical in appearance with the Georgina Limestones. Platy blue limestones precisely similar to those of the Georgina group abound in the lower part of the section. Higher beds have yielded *Eoorthis* and a colossal wealth of echinoderm ossicles. For a considerable thickness these beds are so matted with pelmatazoal plates that they form typical echinodermal limestones. This series I propose to call the Ninmaroo Limestones. In one bed high up in the section on Black Mountain I have found a great wealth of ellesmereoceratid cephalopods, suggesting that these beds belong to the Lower Ozarkian (Lower Tremadocian). I have found no trilobites with them; and the beds so very thick above and below this horizon have not yielded fossils significant for precise correlation. A considerable portion of the Tremadocian no doubt is represented by these limestones.

Thus there is an alternation of lithological types :

Ninmaroo Series	Limestones
Pituri Series	Sandstones and shales
Georgina Series	Limestones
Templeton Series	Sandstones and shales

The changes are abrupt; for, excepting the western development of the Templeton Series, the formations are either wholly calcareous or (except for the cherts) entirely non-calcareous. Yet in spite of this it is to be doubted whether there is any gap in the succession unless possibly at the base of the Ninmaroo Limestones.¹³ There is a remarkable series of faunas that can be correlated individually with zones elsewhere; and the only important gaps in the faunal succession correspond with the unsearched portions of the sequence. This continuity is stressed by the deposition of similar, primary cherts through the Templeton and Georgina Series.

There seems to have been certain marginal faulting in the series as indicated above. In addition two great faults extending roughly east and west occur on Glenormiston. One of these appears to extend for a colossal distance in the Northern Territory, abruptly separating the horizontal Toko Series of the Toko Range, the Tarlton Range and so on, from the Cambrian areas of the Bull Dust Plains in the north. The question may be raised whether this presumed fault is a lateral

¹³ There is a small outcrop of gneiss at the base of Black Mountain. Although this may be a small inlier (and such inliers are known in the Georgina Limestones) it may be suggested that, in Tremadocian times, the basin of deposition has shifted laterally to the east. Another possibility that must be kept in mind is that the lower part of these limestones is equivalent to the Georgina Limestones and that the Pituri Sandstones may be present but have not yet been seen.

continuation of the east-west disturbances of the Macdonnell Ranges. It may be a long while before this problem is solved. These faults, with the folding of the Ninmaroo Limestones and the fault that divides the Cambrian from the Ordovician on Glenormiston, are the only evidences of tectonic disturbance that I have seen in the region.

(d) ON THE USE OF THE TERM CAMBRIAN.

For several reasons it is not easy to delimit the Cambrian development in Australia. One of these is the uncertainty about the base of the Cambrian. Trilobite faunas are first known in the Cordilleran region of North America (*Nevadia* Stage). The earliest Cambrian beds in the Atlantic Province have no trilobites either in Europe or in North America. Preservable trilobite faunas would seem not to have reached that region until later in the Lower Cambrian (*Holmia* Stage). In the province represented by Asia and Australia, which faunally is a unit in the earlier though not in the later parts of the period, the appearance of such faunas was even further delayed, and no trilobite faunas are known earlier than the *Protolenus* Stage although appropriate lower beds, suitable for preserving fossils, occur.

In Australia we do find earlier although non-trilobitic faunas. The most important of these are the archaeocyathinae. But the occurrence of the archaeocyathinae seems so definitely to be determined by climatic factors that, as David (1927) has shown, their stratigraphical position varies considerably in different parts of the globe.

Generally in Australia the base of the Purple Slate Series of South Australia is taken as the base of the Cambrian. It is an acceptable choice ; and in the absence of more definite evidence it serves. The problem of defining the base of the Cambrian does not arise in the area with which I am now concerned, for Cambrian beds earlier than the *Redlichia* Stage do not appear to be present.

A further difficulty is the disagreement between various workers in other lands about the top of the Cambrian.

In 1879, as a compromise between the views of Murchison and Sedgwick on the Lower Palaeozoic relationships, Lapworth proposed the term Ordovician as a period name. He suffered as many intermediaries do ; and today on the continent of Europe the term Ordovician is used not as a period name but as a subdivisional term within Silurian.

In English speaking countries the acceptance of a separate period did not overcome the difficulties of the time, for the limits of the periods were defined on local (English) lithology and diastrophism. Faunal gradations were noted and a number of workers preferred to transfer the uppermost stage of the Cambrian (the

Tremadocian) into the Ordovician. Often it has been stressed since Lapworth's paper that acceptable world-wide divisions should be based on palaeontological grounds. Particularly is this necessary with modern methods of research, and particularly is that need urgent in remote lands like Australia. It is doubtful if a "natural" palaeontological division between Cambrian and Ordovician exists. The base of the Arenig, which Lapworth proposed as the base of the Ordovician, happens to be useful for brachiopod workers since at this stage there is a marked increase in the development of the orthids and strophomenids. For workers on trilobites it is also fairly convenient; but it is not so suitable for those who work on the graptolites.

The assumption that there is a natural division for all faunas is probably unreasonable and certainly unproved. Resser's recent work (1933) on Cambrian horizons is a welcome attempt to clarify the position within the Cambrian. But some international council is needed to define the major boundaries on definite though perhaps arbitrary palaeontological premises, after which, except in special and approved emergencies, no interpolation should be necessary but only subdivision. Almost any horizon would do so long as it is definite.

In 1911 Ulrich complicated the question further by proposing to recognise two other periods between the Cambrian and the Ordovician—Ozarkian and Canadian were the names he chose. As with Lapworth's term Ordovician these new names originally were defined for lithological rather than palaeontological groups. In America the terms have been adopted; but with few exceptions (Kobayashi, Poulsen, Spath and Teichert for instance) they have not been used abroad. Even in America the usage generally is not that originally proposed by Ulrich.¹⁴ Many prefer to take the less debatable viewpoint and, in using the terms, to apply them to subdivisions of pre-recognised periods—Ozarkian as the uppermost division of the Cambrian and Canadian as the basal stage of the Ordovician. As such it is doubtful whether internationally the term Ozarkian strictly has any standing, since on grounds of priority the name Tremadocian takes precedence. Nevertheless it is more convenient than Tremadocian in that it is rather more definitely defined on palaeontological lines. Furthermore it is appropriate since the other major divisions of the Cambrian bear American names.

To depart as little as possible from traditional usage I am adopting in these papers the following nomenclature:—

Ordovician	(Basal Zone— <i>Dichograptus</i>)
Cambrian	{ Ozarkian (Basal Zone— <i>Acerocare</i>)
	{ Croixian (Basal Zone— <i>Agnostus pisiformis</i>)
	{ Acadian (Basal Zone— <i>Paradoxides oelandicus</i>)
	{ Waucobian (Basal Zone— <i>Nevadia</i>).

¹⁴ For a recent statement of his viewpoint see Ulrich, 1924, p. 83.

Ozarkian plus Croixian is the Upper Cambrian in the English sense. Croixian alone is Upper Cambrian in some recent American usage.

For convenience I have used the Scandinavian zonal nomenclature, since there is a pertinent comparison between many Australian and Scandinavian Cambrian faunas. Resser in his valuable paper of 1933 indicates how these zones compare with the Cordilleran sequence.

(e) NOTES ON THE FAUNAL STAGES.

In this little-searched region of nearly 60,000 square miles fossils have been found at only twenty two localities.¹⁵ No less than nine of the twelve faunal stages that now are recognised are known each from the collections from but a single place. A prolonged and systematic search of the sediments will multiply the number of fossiliferous localities and surely also the number of faunal stages. Yet, curiously enough, the faunas that we know cover so aptly the gamut of the beds that few of the pertinent zones in the Scandinavian sequence seem not to be represented. The historical review of our knowledge of these beds shows a progressive addition to the number of faunal stages known since 1929, until which time only the one faunal group had been recognised. Collecting will go on; and perhaps before long these beds will provide a faunal progression that will enable us to make a zonal subdivision more detailed than has been possible in the very condensed sequences of Scandinavia, Shropshire and Newfoundland.

I have stressed the value of the Scandinavian comparisons. Resser recently has urged (1933) that a world-wide zonal nomenclature should be based on American usage. That I think will be so in the future; but the zonal positions of some of the significant faunas of western North America are still uncertain. Time will show which is the best sequence for universal usage. For the present a comparison of the Australian succession with the Scandinavian zones serves most purpose with most of the faunal stages here recorded. In the earlier part of the Cambrian the Australian faunas are closely akin to those of southern and central Asia. But the *Dinesus* Stage marks the coming of a great change in relationships. Thereafter, from about the middle of the Middle Cambrian, there is a curiously close agreement of our faunas with the boreal group of Scandinavia and Siberia. Further comment on this aspect is postponed for the present; but it is worthy of mention that, in many periods of the Palaeozoic and Mesozoic when Australian faunas and floras closely may be compared with groups elsewhere, the close analogies are either with the areas remote from the present equator or else (as in the late Palaeozoic) with intermediate areas that appear to have been cold. Probably until the close of the Mesozoic Australia was one of the colder regions of the globe.

¹⁵ From Chatsworth homestead, one collecting place, the nearest locality from which fossils have been found in a southerly direction is on Glenormiston, 125 miles distant to the south-west.

Most of the localities from which our fossils have come are separated one from another by many miles of country. That being so, when the beds lie so flatly, the stratigraphical succession of the horizons has been determined not by direct observation but by faunal comparisons with sequences elsewhere. In one or two instances, and these are reviewed in the paragraphs that follow, the order of succession of a few related faunas is in doubt. Generally, however, the Scandinavian succession has provided a key to the sequence here, and the sequence so determined has at present no inconsistencies. The review that follows is brief because it is preliminary. It is inopportune to discuss correlations in greater detail until the evidence of the later papers in this series has been presented.

i. THE REDLICHIA STAGE.—Beds with *Redlichia* occur elsewhere in Australia (The Flinders Range, the Kimberley District and the north-west of the Northern Territory). But in the area concerned they have been found at only one locality, Yelvertoft homestead. Species of *Redlichia* and *Aluta* are the only forms known. The types of *Redlichia* that are found in these beds occur in Asia at the top of the Lower Cambrian. The equivalent horizon in Europe and North America would be above the *Protolenus* beds where, on both sides of the Atlantic, there appears to be a gap in the sequence. Other Australian faunas are so like those of the Atlantic Province that I would expect *Redlichia* to be found in the latter region if a complete sequence were available. *Redlichia* occurs above *Protolenus* in China (Saito, 1934) and also, it may be noted, in Australia.¹⁶

The three faunal stages that follow (the *Amphoton*, *Inouyella* and *Dinesus* Stages) appropriately may be bracketed as the *Kootenia* Group. *Kootenia* occurs with *Dinesus* in all three countries where it is known—Queensland, Victoria and Siberia.¹⁷ A doubtful *Kootenia* is found with *Inouyella* in the Northern Territory and the two genera are associated in China. I have not found *Kootenia* in the *Amphoton* Stage of Queensland; but Mr. W. E. Schevill, of the Museum of Comparative Zoology, Harvard, informs me that, in the collections that he made from the type locality of the Stage, Dr. T. Kobayashi has identified *Dorypyge* which possibly represents the same genus. Furthermore in the collections of the University of Queensland from the Heathcoteian beds of Knowsley in Victoria I have recognised the same two trilobites that here are recorded from the *Amphoton* Stage in Queensland.

¹⁶ The rich and varied trilobite fauna at the top of the Archaeocyathinae limestones in South Australia includes several species of *Protolenus*, one of which is the inadequately figured *Ptychoparia howchini* Etheridge Jr. (1919, p. 385, pl. 40, fig. 7). *Redlichia* occurs at a higher horizon in the series.

¹⁷ The Siberian *Solenopleura* (?) *sibirica* (Schmidt) as figured by von Toll (1899, p. 36, pl. 2, figs. 12, 13, and 16) is a typical *Dinesus* occurring with *Kootenia slatkowskii* (Schmidt). *Notasaphus* (Gregory 1903, p. 155) I regard as a synonym of *Kootenia* Walcott.

Mr. D. E. Thomas informs me that these fossils are from his "Dolichometopus Band" in which he finds *Kootenia*¹⁸ (Thomas, 1935, p. 92).

The three faunal stages thus are closely allied. There is, however, no direct evidence of the order of succession. In our province, although *Dinesus* beds are widespread, the *Amphoton* and *Inouyella* Stages are known each from a single locality many miles removed from other places where fossils have been found. *Amphoton* and *Dinesus* beds are associated in Victoria; but whereas in Queensland they are too nearly horizontal for the stratigraphical order to be determined, in Victoria, so I understand, they are too nearly vertical for this to be decided. In Asia, the only other continent where they are recorded, *Amphoton* is found in China and *Dinesus* in Siberia, so that again there is no direct evidence.

In China *Amphoton* occurs in the early part of the range of the *Dorypyge-Kootenia* assemblage and even begins before it. So I have interpreted the *Amphoton* Stage as being earlier than that with *Dinesus*. Some confirmation of this is given by the fact that agnostids have not been found in the *Amphoton* Stage either in Queensland or in Victoria. Agnostids seem to make their first appearance in Australia in beds of the *Dinesus* Stage. The *Inouyella* Stage also has not yielded agnostids. This combined with the fact that it has elements of both the *Amphoton* and *Dinesus* faunas suggests that it occupies an intermediate position. In Victoria, according to Thomas (1935, p. 93), there are not more than 500 feet of strata separating the *Amphoton* (*Dolichometopus*) beds from those with *Dinesus*. It will be interesting to see whether the *Inouyella* fauna will be found in this interval.

ii. THE AMPHOTON STAGE.—From Split Rock, on the main road crossing of Waroona Creek between Camooweal and Mount Isa, soft, yellow siltstones have yielded *Amphoton*, together with a new genus of trilobites and another of brachiopods. As mentioned elsewhere the two trilobite genera are associated also in Victoria. *Dorypyge* (*Kootenia*?) so I understand from Mr. W. E. Schevill, is also present although I have not collected it.

iii. THE INOUELLEA STAGE.—From No. 4 well on Alroy Downs a fauna was obtained in limestones and calcareous shales. This had *Inouyella*, *Lorenzella*, *Anomocarella*, *Kootenia* (?), *XYSTRIDURA* (nom. nov.),¹⁹ *Westonia* and the new genus of brachiopods that is present also in the *Amphoton* Stage.

iv. THE DINESUS STAGE.—A very rich fauna wonderfully well preserved is found on the Templeton River, about 14 miles west of Mount Isa. Brachiopods, conularida and sponges ("*Protospongia*") are plentiful. The trilobites include species

¹⁸ Recorded as *Notasaphus*.

¹⁹ *XYSTRIDURA*, nom., nov. is proposed to replace *Milesia* Chapman (1929, p. 214) which is invalidated by *Milesia* Latreille (1804). *Olenellus browni* Etheridge fil. (1897, p. 13, pl. 1, fig. 1) is selected as genotype.

of *Diplorrhina*, *Triplagnostus*, *Hypagnostus*, *Cotalagnostus*, *Pagetia*, *Dinesus*, *Kootenia*, *Paradoxides* (?), *Xystridura*, *Oryctocephalus*, and *Ptychopariidae*. Of these *Xystridura* is the most abundant. This appears to be the earliest stage that has yielded agnostids either in North-eastern Australia or in Victoria. In Queensland they are varied in genera and prolific in individuals. Equivalent beds with some of this fauna are widespread in the basins of the Thornton, Templeton, Mingera and Buckley waters in Queensland. In the western development of the Templeton Series fossils have been found on Elkedra, Alroy Downs and Alexandria Downs.

The correlation of the stages of the *Kootenia* Group with the zones recognised in other countries is difficult. During this development our Australian faunas are most similar to those of Asia where the zonal positions of the Middle Cambrian faunas are not yet adequately decided. *Kootenia* ranges through a considerable portion of the Middle Cambrian. Since much of the upper part of the Middle Cambrian is represented in the *Anomocare-Phalacroma* beds of the Georgina Limestones and since no fossils have been collected from the basal members of that limestone series it would appear that the *Kootenia* Group should be regarded as equivalent to the basal members of the Middle Cambrian. I would suggest tentatively that the three stages of the group cover the three basal zones of the Middle Cambrian (*Paradoxides oelandicus*, *Triplagnostus atavus* and *Ctenocephalus exsulans*). The abundance of *Triplagnostus gibbus* in the *Dinesus* Stage suggests that these beds represent the uppermost of these three zones.

The stages that have been discussed are in the Templeton Series. As I have just stated no search has been made in the earliest beds of the Georgina Limestones. Collections from these horizons might be expected to yield faunas of other zones.

The three faunal stages that follow, like the three preceding, appropriately might be bracketed together. For this assemblage I suggest the name *Phalacroma* Group.

V. THE PHOIDAGNOSTUS STAGE²⁰.—In the limestones at the margin of the basin eight miles north-east of Duchess *Solenagnostus*, *Enetagnostus*, *Lejopyge*, *Phoidagnostus*, *Phalacroma* and *Lisania* are abundant with brachiopods and "Protospongia." In Europe *Enetagnostus* and *Lejopyge* are found in the zones of *Paradoxides davidis* and *P. forschammeri*, *Lejopyge* continuing further into the zone of *Agnostus laevigatus*. *Phalacroma* ranges from the zone of *P. tessini* to the zone of *P. forschammeri*, *Phoidagnostus* occurs in the last-named zone. The beds with *Anomocare* in Queensland, which appear to represent the zones of *P. forschammeri* and *Agnostus laevigatus*, have *Phalacroma* but it is rare. The Duchess beds, in which

²⁰ Referred to previously (Whitehouse 1931) as the *Leiagnostus* Stage. The reason for the change of name is given later under the section on *Phalacromidae*.

Phoidagnostus and *Phalacroma* are abundant and of generalised types, are presumably slightly earlier and may be correlated with the Zone of *Paradoxides davidis*.

vi. THE ANOMOCARE STAGE.—At the road crossing of Harris Creek north-east of Camooweal there are limestones containing *Anomocare* very close to the genotype. *Euagnostus* and brachiopods occur with it and one specimen of *Phalacroma* has been found. In Europe *Anomocare* appears to be restricted to the Zone of *Paradoxides forschammeri*, with which this stage may be correlated.

vii. THE SOLENOPLEURA STAGE.—This is an unsatisfactory name but must serve for the present. It is used for a fauna found at Chatsworth homestead that contains *Pseudagnostus*, *Anomocare*, *Solenopleura* (?) and brachiopods. In other countries *Pseudagnostus* is recorded no lower than the Upper Cambrian. The coexistence of this genus with *Anomocare* (of a type rather different from that of the genotype) suggests that the horizon is the Zone of *Agnostus laevigatus*. Except at Vestergötland this zone in Europe carries few fossils.

Such a great distance separates the localities that have yielded the *Anomocare* faunas from those where higher faunas have been found that it might be expected that a number of unrecognised faunal stages may be present in the beds of the intervening area. But, curiously enough, none of the Scandinavian zones of this part of the sequence appear to be unrepresented. The stages that follow, and which represent the upper part of the Georgina Limestones, may be bracketed as the *Proceratopyge* group. *Pseudagnostus* (characteristic of the lower part of the Upper Cambrian) occurs in them with *Proceratopyge*. In Scandinavia *Proceratopyge* ranges through the three lowest zones of the Upper Cambrian. In America, under the name *Housia*, it occupies a similarly low, Upper Cambrian position.

viii. THE ANORINA STAGE.—About four miles north of the twenty-mile bore on Glenormiston, the beds with *Pseudagnostus* and *Proceratopyge* are crowded with fossils. In addition to these two genera I have collected *Corynexochus*, *ANORINA* gen. nov.²¹ and a new genus of trilobites that may be a derivative of *Anomocare*. It is rather like certain Siberian forms described by Schmidt.²² Brachiopods and "*Protospongia*" also are abundant. In Scandinavia only one specimen of *Anorina* (*A. superstes* Linnars. sp.) has been found. This came from either the top of the *Olenus* Zone (Moberg 1910, p. 55) or else from the zone of *Orusia lenticularis* immediately above (Westergaard, 1922, p. 182). What its full European range might be in the early part of the Upper

²¹ *ANORINA* gen. nov., genotype *Liostracus* (?) *superstes* Linnarsson (1875, p. 498, pl. 22, figs. 6, 7). The genus is closely similar to the Middle Cambrian *Anoria* Walcott, which recently has been revised by Resser (1935, p. 10) but differs from it in having a non-expanding glabella and non-tuberculate thoracic segments.

²² *Anomocare pawlowskii* Schmidt and *Liostracus maydelli* Schmidt. (See von Toll, 1899).

Cambrian cannot therefore be stated. I believe that the Queensland fauna with *Anorina* is at the base of the Upper Cambrian since it contains not only *Proceratopyge* (ranging downwards to the base of the Upper Cambrian) but also typical *Corynexochus* that in Europe comes to the top of the Middle Cambrian but is not recorded later. Therefore I suggest that this stage represents the Zone of *Agnostus pisiformis*.

ix. THE GLYPTAGNOSTUS STAGE.—At several places from seven to nine miles north of the twenty-mile bore on Glenormiston the blue limestones have yielded only *Glyptagnostus*, *Pseudagnostus*, *Proceratopyge*, and *Olenus* together with brachiopods. *Glyptagnostus* in Scandinavia is confined to the *Olenus* Zone, which is within the range of *Proceratopyge*. In Wales it appears to be on the same horizon. These Queensland beds therefore may be correlated with the *Olenus* Zone.

x. THE PAGODIA STAGE.—In the cabinets of the Geological Survey of Queensland there is a suite of fossils collected by the late Mr. B. Dunstan from fourteen miles south of Glenormiston homestead. The genera present include *Pagodia*, *Eoorthis*, *Hyalithes* and *Lingulella*. Palaeontologically the fauna gives little indication of the precise horizon within the Upper Cambrian; but from the geographical position of the locality the beds would appear to be near the top of the Georgina Limestones. I have searched for but have not found this fauna at the locality stated by Dunstan. From the uppermost beds of the Georgina Limestones, however, I have obtained a new genus of Olenidae.

xi. THE ELATHRIELLA STAGE.—In the lowest beds of the Pituri Sandstones immediately west of Tyson's Bore on Glenormiston I have found *Pseudagnostus*, *Aspidagnostus*, *Olenus* (?), *Elathriella*, *Pesaia* (?) and *Orusia*. The olenid is typical but has rather a wider frontal brim than in the recorded species of *Olenus*. This and the *Pseudagnostus* ally the beds to the underlying *Proceratopyge* Group, suggesting that there is no break in the succession. I would suggest tentatively that this fauna belongs to the Zone of *Orusia lenticularis*.²³

xii. THE ELLESMEREOCERAS STAGE.—Some years ago in the Ninmaroo Limestones of Black Mountain, Warena, Mr. C. Ogilvie found a fauna of abundant echinoderm ossicles and *Eoorthis*. Subsequently I collected the same forms on Mt. Datson. Recently in examining the Black Mountain section I found in beds slightly below the *Eoorthis* horizon a great wealth of ellesmereoceratid cephalopods. No trilobites were found with them. I have not had the opportunity subsequently of re-examining the Mt. Datson section to look for this fauna which is the only determinative assemblage yet found in the thick Ninmaroo Limestones. Ellesmereoceratidae occur in the Lower Ozarkian in many regions. Beyond that, at the moment, it is not possible to make a closer zonal comparison.

²³ *Elathriella* hitherto has been recorded only from Greenland. No other species were found in the same bed. Poulsen (1927, p. 244) was not certain where to place such a new form and tentatively suggested a Lower Ozarkian horizon.

Closing these remarks I would point out that several of the stage and group names here adopted are not perfectly satisfactory so that on some later occasion it may be expedient to change them for more appropriate terms.

As text-figure 4 I give a table of suggested correlations of the Cambrian horizons of Australia. This has been based on a re-examination of the faunas from all the Australian horizons except the Dolodrook Limestone of Victoria and the beds of the Kimberley District. These latter collections, housed in the National Museum (Melbourne), have not been available to me.

	EUROPEAN ZONES.	AUSTRALIAN FAUNAL STAGES.	NORTH-EAST AUSTRALIA.	VICTORIA & TASMANIA.	SOUTH AUSTRALIA.	WESTERN AUSTRALIA.
OZARKIAN	Upper Ozarkian (Undifferentiated)	<i>Asaphellus</i>		XXXXX Tasmania		
	Lower Ozarkian (Undifferentiated)	<i>Ellesmereoceras</i>	XXXXX Ninmaroo Limestones			
CROIXIAN	<i>Acerocare</i> <i>Peltura longicornis</i> <i>Peltura scarabaeoides</i> <i>Peltura minor</i> <i>Ctenopyge</i> <i>Eurycare</i>					
	<i>Orusia lenticularis</i> <i>Olenus</i> <i>Agnostus pisiformis</i>	<i>Elathriella</i> <i>Pagodia</i> <i>Glyptagnostus</i> <i>Anorina</i>	XXXXX Pituri S. stones			
	<i>Lejopyge laevigatus</i> <i>Paradoxides forschammeri</i> <i>Paradoxides davidis</i> <i>Conocoryphe aequalis</i> <i>Hypagnostus parvifrons</i> <i>Paradoxides hicksi</i> <i>Ctenocephalus exsularis</i> <i>Triplagnostus atavus</i> <i>Paradoxides oelandicus</i>	<i>Solenopleura</i> <i>Anomocare</i> <i>Phoidagnostus</i>	XXXXX Georgina Limestones	????? Victoria		
		<i>Dinesus</i> <i>Inouyella</i> <i>Amphoton</i>	XXXXX Templeton Series	XXXXX		
ACADIAN		<i>Redlichia</i>				
WAUCOBIAN	<i>Lapworthella</i> <i>Protolenus</i> <i>Strenuella</i> <i>Eodiscus bellimarginatus</i> <i>Callavia</i> <i>Holmia kjerulfi</i> <i>Acrothele prima</i> <i>Obolella groomi</i> <i>Volborthella</i> <i>Platysolenites</i> <i>Discinella holsti</i>	<i>Protolenus</i> <i>Archaeocyathus</i>			XXXXX XXXXX XXXXX Purple Slates & Limestones	XXXXX Kimberley Sequence

TEXT. FIGURE. 4.

SUGGESTED CORRELATION OF
AUSTRALIAN CAMBRIAN HORIZONS.

Part 2. PALAEONTOLOGY.

Subclass TRILOBITA Walch 1768.

Order MIOMERA Jaekel 1909.

I have used Jaekel's classification of the trilobita into Miomera and Polymera, believing that it best expresses the major natural divisions of the group.

The small agnostid and eodiscid trilobites with large head and tail shields and few thoracic segments differ so strikingly from the other groups that they require separate placing. No transitions have been recorded between these two major divisions. Furthermore, even among the large trilobites with many thoracic segments and variable pygidia (the Polymera of Jaekel), there are many natural divisions that cannot be joined at present by known connecting links. The Lower Cambrian polymerid trilobites, for instance, include the blind Mesonacida (which lead apparently to Redlichiidae and Paradoxididae) in which the pygidium is tiny, and Corynexochidae with eyes and large pygidia. No intermediate forms are known. Ellipsocephalidae also is isolated.

There must have been a long Pre-Cambrian ancestry of the trilobites during which the segments of the head fused to form the compact shield that we know. Jaekel (1901) has suggested how this fusion may have taken place. According to this idea there were eight segments in the cephalon represented by the hypostome, the rostrum, five glabellar segments and the occipital ring.

The larval stages of *Elliptocephala* (Walcott 1910) suggest that the palpebral structures are pleural developments of which the axis is the first glabellar lobe, and that furthermore the post-palpebral portions of the fixed cheeks are the pleura of the remaining glabellar segments. I prefer to believe that the segments of the head were as follows:—

1. The hypostome.
2. The rostrum.
3. The pre-palpebral fixed cheeks to which the free cheeks are the pleura.
4. The 1st glabellar lobe and the palpebral structures.
- 5-7. The 2nd to 4th glabellar lobes and the post-palpebral portions of the fixed cheeks.
8. The occipital structures.

Considering that there must have been a long period for the fusion of the cephalon, whatever be the details of the fusion, and remembering the variety of the trilobite groups when first they are known in the Lower Cambrian, it is reasonable to suggest that the early trilobite stock had a soft carapace and that independent lineages separately developed hardened tests. The strange and isolated genera *Marella*

Walcott²⁴ of the Middle Cambrian and *Mimetaster* Gürich (1930) of the Devonian, each with little hard carapace, suggest that at least until the Devonian soft forms may have persisted and that they developed offshoots that were slightly more specialised than the trilobites.

The trilobites with hard dorsal tests vary within wide limits. Anagenetic and catagenetic changes simultaneously operate on separate divisions of different lineages. Some forms become smooth by the elision of surface detail while related forms increase their ornament. Glabellar furrows increase and diminish. Eyes appear and disappear. The number of thoracic segments varies, and so on. If there has been this variation in palaeozoic periods when hard-shelled forms occur it is well to suppose that it operated previously. Thus it is only to be expected that the earliest known trilobites belong to a number of circumscribed and differentiated groups.

I would suggest that in Pre-Cambrian times the soft ancestors of the trilobites separated into at least two major groups. One of these, a short-lived section, developed hard tests in two main lineages (Eodiscidea and Agnostida) and are preserved as the Miomera. In the other, in which there was considerable variation, tests developed in several lineages. One of these (Mesonacida) like Miomera, was blind when their earliest testiferous members appeared, but facial sutures later arose along an old fusion line. In others (Corynexochidae, Ellipsocephalidae, Menomonidae, Burlingidae, etc.) the development of facial sutures preceded the hardening of the test. It may be that certain post-Cambrian families independently arose from the soft polymeran stock; but further discussion of these relationships is postponed to other occasions.

Within Miomera there are two major divisions—Eodiscidea that originally has three thoracic segments, though in some forms (*Pagetia*) they may be reduced to two, and Agnostida which always has two segments in the thorax. Both groups are present in north-eastern Australia.

Suborder EODISCIDEA Richter.

Eodiscids first appear in the Lower Cambrian. The typical form of the group is a small, blind trilobite with subequal, subcircular cephalon and pygidium and with three segments in the thorax. In the Middle Cambrian specialised forms develop facial sutures and palpebral structures. Of these *HEBEDISCUS* gen. nov.²⁵ and

²⁴ Dacque (1921, p. 703) and Ruedemann (1931, p. 9) each has suggested that *Marella* is a trilobite in the period of ecdysis. The anterior appendages, however, suggest that it is a variant from the trilobite stock.

²⁵ *HEBEDISCUS* gen. nov., genotype *Ptychoparia attleboroensis* Shaler and Foerste (1888, p. 39, pl. 2, fig. 14), has strong palpebral ridges and lobes, traces of glabellar furrows and proparian facial sutures. The pygidium is smooth, with a strong axis extending to the posterior rim. Cobbold (1931, p. 462, pl. 38, figs. 1-6), who referred the genotype tentatively to *Pagetia*, figured a complete form showing that there were three segments in the thorax.

Delgadoia Vodges²⁶ retain the three thoracic segments but *Pagetia* has only two. *Dipharus* Clark (1923, p. 478) has been included in Pagetiidae by Kobayashi (1935b, p. 112). It is so small that possibly it is a larval form. It may be the immature stage of a pagetiid, as Cobbold (1931, p. 465) has suggested. But equally well it could be the larval stage of a polymerid trilobite.

The genera of the eodiscids that are known to have had eyes and facial sutures differ considerably. *Delgadoia*, with simple shields, is similar in many ways to the blind *Weymouthia*, differing in having eyes and faint axial structures. *Pagetia* differs from *Calodiscus* only in the eye structures and in the reduction of the number of thoracic segments from three to two. *Hebediscus*, which retains the eodiscid features of a tuberculate rim and three thoracic segments, is an even more specialised form. It has well developed palpebral ridges and glabellar furrows that make it more like a polymerid trilobite than any other member of the Miomera. *Pagetia* also has these structures, though they are somewhat spasmodically developed, so that possibly *Pagetia* and *Hebediscus* are not far removed genetically. *Delgadoia* differs so much from them and resembles closely certain blind members of the group that it is probable that the eodiscids with facial sutures have arisen polyphyletically from the blind forms of the suborder. In Pagetiidae, which most nearly concerns me at the moment, I include only *Pagetia*.

Blind eodiscids have not been found in Australia, so that there is no need to comment upon them here. I would merely record that I agree with Etheridge (1919, p. 383) that *Microdiscus subsagittatus* Tate (1892, p. 187), from the Lower Cambrian (*Protolenus* Stage) of South Australia, is not a member of Eodiscidea.

Family PAGETIIDAE Kobayashi 1935b.

Genus **PAGETIA** Walcott 1916b.

Genotype: *Pagetia bootes* Walcott 1916b.

PAGETIA SIGNIFICANS (Etheridge fil.)

Pl. VIII, figs. 1-5.

1902 *Microdiscus significans* Etheridge Jr., p. 3, pl. 2, figs. 5-9.

1919 *Microdiscus significans* Etheridge Jr., p. 380.

1927 *Eodiscus significans* Whitehouse, p. vii.

1930 *Pagetia* Whitehouse, p. 27.

1931 *Pagetia* Whitehouse, p. 141.

Etheridge described this species in the following terms:—

“Cephalon semicircular, convex, margined by a continuous flattened limb, which is itself bordered by a raised rim, the former bearing a series of close elongated tubercles; glabella more or less biconical, unlobed, smooth, angular in the middle line longitudinally, produced backwards as a process or spine

²⁶ *Delgadoia* Vogdes (1917, pp. 27 and 81), generally has been overlooked by workers on the eodiscids. *Delgadodiscus* recently proposed by Kobayashi (1935b, p. 112) is a synonym, the genotype of both being *Microdiscus caudatus* Delgado (1904, p. 349, pl. 3, fig. 12).

over the posterior cephalic margin. Axial furrows strong and wide; cheeks tumid, smooth, well-defined by the surrounding furrows; postero-lateral angles apparently truncate. Thorax unknown. Pygidium semicircular with a well-defined limb, and the antero-lateral angles truncated as if for facets; axis narrow, convex, extending completely to the posterior margin of the pygidium and composed of six segments, each bearing a central blunt tubercle directed backwards; pleurae also convex, but less so than the axis, of five segments, without tubercles or other ornament. Size of cephalon two and a half millimetres wide by two long, inclusive of the spine; size of pygidium, three millimetres broad by two long."

The description of the material is good and the figures show the essential features of the species. Photographs of two of the types are reproduced on plate VIII of this paper.

When the species was described originally the name *Pagetia* had not been proposed; but subsequently, in view of Walcott's description of the genus, Etheridge re-examined the original specimens. He then remarked (1919, p. 380) that he had "failed to find any trace of either 'eye line' (palpebral ridge) or eyes." To his original description he then added that "the surface of each cheek rises into a low blunt tubercle."

Etheridge's specimens were all contained in the one rock specimen that Davidson collected at Fossil Hill, 40 miles south east of Elkedra. Subsequently the species has been found in great abundance on the Templeton River. At this locality the individuals frequently reach a larger size than the forms found by Davidson; and with the larger size there comes certain changes in features. Nevertheless I do not think that the two groups should be separated specifically.

In spite of Etheridge's statement that his specimens show no trace of eyes the margins of the cheeks of many of his specimens are broken away in the position of the facial suture of *Pagetia*. This often is so regular (e.g. on the lectotype now refigured) there can be no doubt that a true facial suture was present. The Templeton River forms show this often very clearly (pl. VIII, fig. 3).

The specimens from Elkedra and also the smaller individuals from the Templeton River show no trace of palpebral ridges or glabellar furrows; but in the larger forms from the latter locality these features occasionally may be seen. The cephalon figured as plate VIII, figure 3 has two pairs of glabellar furrows, the anterior pair being continuous and the posterior part discrete. Also on this specimen traces of palpebral ridges may be discerned. These features are decidedly spasmodic in their development. On forms of the maximum size they are not always present. Some large specimens have neither of these features. Others have one of them, while occasionally both are present. Also they vary in intensity when they do occur.

Another feature that varies with the size of the individual is the pitting of the cephalic rim. The pits are radially elongate. In young forms they are equal; but in older forms they are alternately long and short.

Generally the features of the species may be summarised as follows:—

The cephalon is semicircular with a conical glabella that is simple in the young forms but which, in older individuals, sometimes develops two pairs of furrows. There is a spine on the posterior portion of the glabella that overhangs the occipital furrow. The fixed cheeks join in an attenuated pre-glabellar region and become progressively more inflated from this junction towards their posterior limits. The free cheeks are narrow and occur immediately beyond the inflated edge of the fixed cheeks. The facial sutures are typically proparian, their anterior and posterior limbs being bent normal to the margin. In large specimens palpebral ridges sometimes cross the inflated fixed cheeks parallel to the posterior margin. On the rim the pittings are radial slits that are simple in the smaller forms but, with increasing age, they become alternately long and short.

There are two thoracic segments. The axis has faint median tubercles. The pleura have furrows, the sides of which are parallel to the pleural edges. The extremities of the pleura are rounded.

There are six prominent rings on the axis of the pygidium. The anterior five bear median tubercles while the sixth has a long spine that seems to have been of delicate construction for often it is broken away leaving a tubercle in its place. On each pleuron of the pygidium there are five ridges, extending obliquely from the axial rings, with their crests marked by shallow, longitudinal grooves. There is a narrow, flat rim to the pygidium, and over the posterior portion of this the axial spine projects.

There seems to be only three other described species that can be included in *Pagetia*. These are the genotype (*P. bootes* Walcott), *P. clytia* Walcott and the Indian *P. griesbachi* (Reed). Neither *P. bootes* nor *P. clytia* (Walcott 1916b, p. 408, pl. 67, fig. 2) has the pygidium furrowed as in *P. significans*, nor are the fixed cheeks inflated to such a degree. In each of these American species two pairs of glabellar furrows, similar to those that occasionally appear on *P. significans*, are sometimes present. *P. bootes* also has similar palpebral ridges. *P. griesbachi* (Reed 1915, p. 6, pl. 1, figs. 4-11) is more closely related to the Australian form. It has the same specialised types of fixed cheeks and pygidium. The only differences are that there are but four pairs of grooved pleural furrows on *P. griesbachi*, while also it is a slightly smaller form.

The specimen figured by Etheridge on plate 2, figure 7 of his paper is here chosen as the lectotype. This cephalon is refigured on plate VIII, figure 4 of the present paper. Another of Etheridge's specimens (his plate 2, figure 9) is shown on my plate VIII, figure 5.

Localities and horizon.—The lectotype and the cotypes come from Fossil Hill, 40 miles south-east of Elkreda homestead and are in the Australian Museum Collection. Other forms are from the Templeton River (University of Queensland and the Geological Survey of Queensland Collections) and also from the crossing of Buchanan's Creek, between Alroy and Alexandria homesteads (University of Queensland Collection). The horizon is the *Dinesus* Stage.

Order AGNOSTIDA Kobayashi 1935b.

So much work remains to be done on the agnostids that it is not possible to make a family review of the group. The earliest forms include among other genera *Triplagnostus*, *Diplorrhina* and *Hypagnostus* each of which may stand at the head of a separate family. *Triplagnostus* and *Goniagnostus* with their characteristic pair of glabellar furrows are related to *Solenagnostus* and *Agnostus* in which these have disappeared. Further simplification in *Agnostus* leads to *Euagnostus*. All these genera, together with ONCAGNOSTUS, gen. nov.²⁷ and *Fallagnostus*, I have grouped in Agnostidae. A more general simplification from this stock seems to have produced Phalacromidae in the Middle Cambrian. Smooth forms like *Phalacroma* are known also in the Lower Ordovician; but since they occur also, although rarely, in the Upper Cambrian, I have preferred to regard these too as members of Phalacromidae. Similarly, until it can be shown that the group is polyphyletic, I place *Diplorrhina*, which begins early in the Middle Cambrian, in Geragnostidae which Howell proposed for certain Upper Cambrian forms. I do not think it necessary to multiply family names in a morphologically knit group until polyphyletic derivation is reasonably certain. Where a small group has characters that are not known to be repeated (e.g. Glyptagnostidae, Diplagnostidae, etc.) I have used family names for small natural assemblages.

Family AGNOSTIDAE McCoy 1849.

Genus **TRIPLAGNOSTUS** Howell 1935c.

Genotype: *Agnostus gibbus* Linnarsson 1869.

TRIPLAGNOSTUS GIBBUS (Linnarsson).

(Pl. VIII, figs. 6, 7; pl. X, figs. 1 (pars) and 2.)

1869 *Agnostus gibbus* Linnarsson.²⁸

1880 *Agnostus gibbus* Tullberg, p. 15, pl. 1, fig. 2.

1935c *Triplagnostus gibbus* Howell, p. 14, pl. 1, figs. 5, 6.

This species is extraordinarily abundant in the *Dinesus* Stage of the Templeton River where the bedding planes often are matted with the shields of the trilobite.

²⁷ ONCAGNOSTUS gen. nov., genotype *Agnostus hoi* Sun (1924, p. 28, pl. 2, fig. 2), has a glabella similar to *Agnostus* (s. str.) but the pygidium, which bears marginal spines, has a sack-like axis that extends to the posterior rim. This axis has two furrows and a median tubercle. *Agnostus hoiformis* Kobayashi (1933, p. 97, pl. 10, figs. 1-3) is another member of the genus.

²⁸ I have not had access to Linnarsson's paper and cannot quote the pagination for the species.

Professor Grönwall of Lund has kindly supplied me with some Swedish specimens of the species with which I have made a close comparison. The Queensland forms have the following features which are characteristic of *T. gibbus*.

The glabella is narrow with subparallel sides.

The transverse furrows of the second glabellar lobe are faint.

The accessory glabellar lobes are small.

The occipital spine is prominent.

The pleura of the pygidium are separated by a faint posterior furrow.

The axial tubercle of the pygidium is prominent and superimposed on the second transverse furrow.

T. gibbus and the closely related *T. hybrida* (Brögger) occur in the zone of *Conocoryphe exsulans* in Sweden.

Localities and horizon.—The species occurs in the *Dinesus* Stage of the Templeton River (University of Queensland and Geological Survey of Queensland Collections) and at the Thornton River above Thornton homestead (Australian Museum Collection).

TRIPLAGNOSTUS ATAVUS (Tullberg).

(Pl. VIII, figs. 8, 9; pl. X, fig. 1 (pars).)

1880 *Agnostus atavus* Tullberg, p. 14, pl. 1, fig. 1.

Triplagnostus atavus, another early member of the genus, is present in Queensland. A large number of complete specimens have been collected from Yelvertoft Station in Queensland. A noticeable feature is that the larger the specimen the more prominent are the radial furrows of the cephalon. The smallest forms are almost devoid of these grooves.

The Australian forms agree with the type (as figured by Tullberg) in the following features:—

The cephalon is ornamented with alternately long and short radial furrows.

The glabella narrows anteriorly in a very regular way.

The transverse furrows of the posterior glabellar lobe are prominent.

The accessory lobes are transversely divided by a shallow furrow.

The pygidium has no radial ornament.

The pygidial axis has the sides parallel in the middle portion, but the sides diverge anteriorly and converge posteriorly.

The axial tubercle of the pygidium is immediately anterior to the second transverse furrow.

Tullberg figured only one pygidium. On that the pleura were separated posteriorly by a longitudinal furrow. This furrow is a variable feature in the Queensland forms. On specimens on the one slab it sometimes is prominent, sometimes faint, and sometimes not present at all.

Localities and horizon.—One specimen (in the University of Queensland Collection) has been obtained from the *Dinesus* Stage of the Templeton River. Many complete specimens are in the collections of the University of Queensland and the Geological Survey of Queensland from Yelvertoft Station in Queensland. These have been presented by the owner of the station, Mr. W. Dalling. Both *Redlichia* and *Dinesus* beds are present on this property. It may be that the specimens come from the *Dinesus* beds, since the species occurs on this horizon at the Templeton River. But since it is rare at the latter locality and abundant at Yelvertoft and since in Europe it occurs in beds immediately below those with *T. gibbus*, it is possible that it may occur on some slightly earlier horizon here.

Genus **SOLENAGNOSTUS** gen. nov.

Genotype: *Agnostus longifrons* Nicholas 1915.

Diagnosis.—Agnostids very similar to *Agnostus* (s. str.) from which they differ in having a prominent, incised, post-axial furrow on the pygidium. The pygidial axis has two furrows and a median tubercle.

SOLENAGNOSTUS ACUMINATUS sp. nov.

(Pl. VIII, figs. 13-16.)

Diagnosis.—Cephalon subcircular, widest in the middle region and with a slight median embayment of the anterior margin. Rim very narrow. Glabella tapering rapidly to the front, the anterior margin acute. The length of the glabella is about two-thirds the total length. Anterior lobe triangular and relatively large, bounded posteriorly by a sharply defined furrow. Accessory lobes very small, triangular. The cheeks are moderately inflated and are separated by a sharp, narrow, pre-glabellar furrow that extends to the rim. There is no median tubercle.

The pygidium is widest at the anterior margin. Its rim is wider than that of the cephalon. The axis is lanceolate, occupying about two-thirds the length of the shield and one-third of the width. The two transverse furrows are sharp and centrally divergent. The median tubercle is on the posterior portion of the middle lobe. The post-axial furrow is prominent. Marginal spines do not appear to be present.

Remarks.—There are not many figured species that may be placed in *Solenagnostus*. *S. lundgreni* Tullberg sp. (1880, p. 20, pl. 1, fig. 8) is perhaps the closest form, having similar outlines and rims and a similarly acute glabella. However, the axis of the pygidium is wider than in *S. acuminatus* and the anterior lobe of the glabella is smaller. *S. longifrons* Nicholas sp. (1915, p. 453, pl. 39, fig. 1) has a comparably large anterior glabellar lobe but the glabella has subparallel sides and the shields generally are more elongate.

Localities and horizons.—From the *Dinesus* Stage of Yelvertoft and the *Phoidagnostus* Stage eight miles north-east of Duchess (University of Queensland Collection).

Genus **EUAGNOSTUS** gen. nov.

Genotype: *Euagnostus opimus* sp. nov.

Diagnosis.—Agnostids with the cephalon having the same features as *Agnostus* but sometimes without a pre-glabellar furrow. The axis of the pygidium is large, extending almost to the posterior rim, but it is not divided by transverse furrows. A small post-axial furrow is present on the pygidium separating the pleura.

Generally the features recall *Diplorrhina*; but the presence of the pre-glabellar furrow in many specimens suggests that it is a separate development.

EUAGNOSTUS OPIMUS sp. nov.

(Pl. VIII, figs. 10-12.)

Diagnosis.—The individuals are large with contours and furrows (the latter well defined) in graceful curves.

The outline of the cephalon is a perfect arc of a circle. The cephalon is uniformly domed and is widest in the posterior region at about one-third of the distance from the margin. The rim gradually widens anteriorly and has a furrow of equal size behind it. The glabella narrows anteriorly but persists for about two-thirds the length of the shield. The accessory lobes are small and triangular. The furrow between the anterior and posterior lobes is shallow. The pre-glabellar furrow is short, the cheeks contracting anteriorly, leaving a median triangular space behind the rim. This furrow is shallow; and in some specimens is not retained.

The pygidium is transversely elongate. Its axis is large, roughly equal in area to the two pleura. It has no transverse furrows, although a slight shallowing, at about one-fifth of the length from the anterior margin, suggests a rudimentary anterior furrow. Immediately behind this is a very faint tubercle. The axis extends almost to the posterior rim. The circum-axial and the post-axial furrows are deeply incised. The rim is large and in the postero-lateral corners is separated from the pleura by a slightly flattened area. Rudimentary postero-lateral spines are present.

Remarks.—Tentatively I would place in *Euagnostus* the Scandinavian *Agnostus exaratus* Grönwall (1902, p. 77, pl. 1, fig. 17). The holotype is a pygidium. Under this name Lake (1906, p. 6, pl. 1, figs. 8-10) has figured a Welsh form with cephalon attached. No pre-glabellar furrow is present in that form. In shape it differs noticeably from *E. opimus*. *Agnostus interstrictus* White (see Walcott 1886, p. 149, pl. 16, fig. 6) also appears to belong to the genus and is the form most similar to *E. opimus*.

Locality and horizon.—From the *Anomocare* Stage, 52 miles from Camooweal, on the road from Camooweal to Thornton Station (University of Queensland Collection).

Family GERAGNOSTIDAE Howell 1935b.

Howell proposed two family names Geragnostidae and Micragnostidae for agnostids without a pre-glabellar furrow and with a simple pygidial axis. This I think is an unnecessary refinement. The genera included were *Geragnostus* Howell, *Micragnostus* Howell and *Anglagnostus* Howell. If to these we add *Diplorrhina* Corda and *Peronopsis* Corda the assemblage is a group of genera, ranging from early Middle Cambrian to early Ordovician, that have many features in common. Provisionally I would set all five genera in Geragnostidae.

Genus **DIPLORRHINA** Corda 1847.

Genotype : *Agnostus sirius* Corda 1847.

DIPLORRHINA ELKEDRAENSIS (Etheridge fil.).

(Pl. IX, figs. 3, 4.)

1902 *Agnostus elkedraensis* Etheridge Jr., p. 3, pl. 2, figs. 5-9.

1919 *Agnostus elkedraensis* Etheridge Jr., p. 379.

non 1927 *Agnostus elkedraensis*, Whitehouse, p. vii.

Etheridge described this species in the following words :—

“Cephalon and pygidium of nearly equal size and shape, and more or less generally resembling one another; whole body five millimetres long. Cephalon practically equal in length and breadth, regularly rounded in front, and the lateral margins sub-parallel; postero-lateral angles apparently truncated; anterior and lateral borders formed by a continuous raised limb, separated from the cheeks by a similar groove; cheeks gently convex and smooth, rather wider laterally than anterior to the glabella; dorsal furrows well defined and encircling an oblong, smooth, gently convex glabella, which narrows a little towards the anterior, and is traversed by one furrow, more anterior than posterior, dividing the glabella into two unequal lobes, the anterior or smaller of which bears a central small tubercle; supplementary lobes, small and node-like, placed one on either side at the base of the glabella. Thorax very short, of one segment only, consisting of a wide axis, and tubercle-like pleurae. Pygidium resembling the cephalon in outline, with a similar raised limb and boundary furrow; length and breadth about equal, except at the posterior end, where there is a perceptible narrowing; incipient spines at the postero-lateral angles and along the lateral margins absent; antero-lateral angles truncated, as if by facets; axial lobe longer than the glabella, and approaching nearer to the posterior border of the pygidium than the glabella does to the anterior border of the cephalon, generally convex, with a central tubercle placed at the anterior end; surface smooth, and no segmentation; axial furrows well defined; lateral lobes (answering to pleurae) gently convex and smooth.”

No further specimens of the species have been collected, so that there is little to add to the account. There are but two aspects that need comment. Etheridge mentions that there is only one thoracic segment; and in later remarks he infers from this that the individuals were immature. However only two complete carapaces are preserved and each of these is slightly distorted so that possibly, in the slight rotation, they partly obscure the thoracic segments.

The margin of the pygidium is uniform and Etheridge mentioned that there are no marginal pygidial spines. But in one or two specimens rudimentary spines (really angular developments of the margin) are to be seen. They can be discerned faintly on the cotype figured as plate IX, fig. 4 in the present paper. It would seem that there was an angular development from the margin projecting not laterally but ventrally and this is seen only on occasional specimens that may have been pressed somewhat obliquely on the slab.

In its cephalic features (the presence of strong circum-glabellar and intra-glabellar furrows and the absence of a pre-glabellar furrow) and also in the long, wide unfurrowed pygidial axis the species is a typical member of *Diplorrhina*. The arcuate outline of the head is somewhat more regular than in most species of the genus.

The specimen figured by Etheridge as figure 1 on his plate is chosen as lectotype and is here refigured on plate IX, fig. 3. The specimen now figured as plate IX, fig. 4 is the cotype that Etheridge showed in his second figure.

Locality and horizon.—The *Dinesus* Stage of Fossil Hill, forty miles south-east of Elkreda (Australian Museum Collection).

DIPLORRHINA NORMATA sp. nov.

(Pl. IX, figs. 1, 2.)

1927. *Agnostus elkedraensis* (non Eth. fil.) Whitehouse, p. vii.

1929 *Agnostus chinensis* (non Dames) Chapman, p. 208, pl. 21, fig. 6; pl. 22, fig. 20.

Diagnosis.—Cephalon subquadrate, slightly arcuate in front. Posterior lobe of the glabella sub-rectangular. The anterior lobe of the glabella, separated posteriorly by a prominent groove, is perceptibly narrower than the posterior lobe. Circum-glabellar furrow prominent. Accessory lobes very small. Cheeks U-shaped, the circum-glabellar furrow being noticeably concentric with the margin of the cephalon. Rim of moderate size bounded interiorly by a narrow prominent furrow.

There are two thoracic segments in which both axis and pleura are convex.

Pygidium sub-rectangular, relatively shorter than the cephalon. The axis is large, the lateral margins parallel and the posterior margin obtusely angular. It

reaches almost to the rim. There are no axial furrows. A small, longitudinally elongate tubercle is placed at the base of the anterior third of the axis. The pleura are narrow, converging posteriorly. The rim is slightly convex increasing in width to the postero-lateral angles where obtuse marginal spines are present.

Remarks.—Previously I had identified this form as *D. elkedraensis* (Eth. fil.) ; but it should be removed from that species on account of its more quadrate outline. Chapman regarded it as identical with *Agnostus chinensis* Dames ; but Kobayashi (1935b, p. 102) has pointed out that Walcott (1913) grouped two distinct forms under this name. One of these he separated under the new name *Agnostus rakuroensis*. This species, which is a *Diplorrhina*, is probably the form that Chapman had in mind. *D. normata*, although particularly like *D. rakuroensis*, differs in certain minor features such as the nature of the postero-lateral regions of the pygidium and the larger size of the accessory lobes of the glabella. The Indian *D. spitiensis* Reed sp. (1910, p. 4, pl. 1, figs. 1-3) is quite different, having more rounded contours, a glabellar tubercle and a non-spinous pygidium. Among the North American species *D. montis* Matthew sp. (1899, p. 43, pl. 1, fig. 6) may be compared and also *D. acadicus* Hartt sp. (as figured by Walcott 1884b, p. 27, pl. 2, fig. 2).

Locality and horizon.—Very abundant in the *Dinesus* Stage of the Templeton River (University of Queensland and Geological Survey of Queensland Collections).

Family DIPLAGNOSTIDAE fam. nov.

It is proposed to unite in the one family the three Middle Cambrian genera *Diplagnostus* Jaekel, *Tomagnostus* Howell and *Enetagnostus* Whitehouse. In each the glabella has two primary lobes and two small accessory lobes. The anterior glabellar lobe has a median sulcus and there is a pair of medio-lateral depressions on the posterior lobe. The median sulcus of *Diplagnostus* is in the form of a furrow bisecting the anterior lobe. In *Tomagnostus* it is a small anterior structure. In *Enetagnostus* it is a depression rather than a furrow. The medio-lateral depressions of the posterior glabellar lobe are analogous in position to the furrows of *Goniagnostus* and *Triplagnostus*, but are merely rudiments.

There is a marked similarity between the pygidia of *Diplagnostus* and *Enetagnostus*. *Tomagnostus* differs in not having the divided posterior rim and in the absence of marginal spines.

Tomagnostus and *Diplagnostus* are found in the middle of the Middle Cambrian. *Enetagnostus* would appear to represent the later part of the Middle Cambrian (from the zone of *Paradoxides davidis* to the zone of *P. forschammeri*).

Genus **ENETAGNOSTUS** gen. nov.

Genotype: *Enetagnostus humilis* sp. nov.

Diagnosis.—Agnostids with well-defined circum-glabellar and transverse furrows on the cephalon, and two small, accessory glabellar lobes. Anterior glabellar lobe obtuse, with a shallow, median, longitudinal depression. Posterior glabellar lobe with a pair of shallow, medio-lateral depressions. The frontal portion of the cheek is marked by a faint longitudinal furrow. Thorax unknown. Pygidium with the rim divided in the posterior portion and with distinct or rudimentary marginal spines. Pygidial axis lanceolate, feebly trilobed, with a large, elongate, median tubercle.

ENETAGNOSTUS HUMILIS sp. nov.

(Pl. VIII, figs. 17-19.)

Diagnosis.—Cephalon moderately inflated, with a regularly curved margin rather semicircular in shape. Rim narrow, declining at the postero-lateral angles. Glabella with sub-parallel sides (very slightly contracting anteriorly) and extending for about two-thirds of the length of the cephalon. Anterior glabellar lobe subquadrate, bounded posteriorly by a shallow sulcus and bearing a median longitudinal depression. Accessory lobes small but transversely elongate. The cheeks are separated anteriorly by a shallow narrow pre-glabellar furrow.

Pygidium subquadrate with rounded posterior margin. Small postero-lateral spines are borne. Posteriorly the rim divides into two ridges enclosing a lunate area. The axis is broad and shield-shaped extending almost to the first ridge of the posterior rim. It has two pairs of discontinuous transverse furrows and bears a large though not a prominent ovate, median tubercle.

Remarks.—Comparison may be made with *E. kjerulfi* Brögger sp. (1878, p. 149, pl. 5, fig. 7), *E. arcticus* Holm and Westergaard sp. (1929, p. 13, pl. 1, figs. 26-30), *E. (?) vestgothicus* Wallerius sp. (1930, p. 58). The pygidium of the last-named species is most similar to that of *E. humilis*, but the cephalon is very different having radial ornament. The presence of such radial furrows makes it difficult to decide whether *E. vestgothicus* belongs to *Enetagnostus* or *Diplagnostus*; but the strong central groove suggests the former genus. In both *E. kjerulfi* and *E. arcticus* the first ridge of the divided posterior rim of the glabella is irregular. Also the axial tubercle of the pygidium is more elongate. Westergaard (Holm and Westergaard 1929, p. 13) has pointed out that the form figured by Grönwall (1902, p. 69, pl. 1, fig. 11) as *Agnostus kjerulfi* is specifically distinct. Actually in that form there is little trace of a division in the posterior rim. Probably the Welsh form figured by Nicholas (1915, pl. 39, fig. 3) as *Agnostus kjerulfi* is the same species as that figured by Grönwall.

Locality and horizon.—From the *Phoidagnostus* Stage eight miles north-east of Duchess (University of Queensland Collection).

Family PHALACROMIDAE Corda 1847 (emend.)

Corda (1847) placed in the Phalacromides his genera *Phalacroma*, *Selenoptychus*, *Mesospeniscus*, *Diplorrhina*, *Condylopyge* and *Lejopyge*. It was an unwieldy grouping. In 1909 Jaekel erected the family Leiagnostidae for the smooth agnostids and placed in it his two genera *Leiagnostus* and *Miagnostus*. Unfortunately Jaekel quoted but ignored Corda's work, and *Miagnostus* is a synonym of *Lejopyge* (the genotype of each being *Battus laevigatus* Dalman) while morphologically *Leiagnostus* is an equivalent of *Phalacroma*. In 1913 Raymond restricted Phalacrominae to "agnostids with shields scarcely lobed" and included in it only the two genera *Phalacroma* and *Lejopyge*. He thus interpreted the sub-family in precisely the same way as Jaekel had done with Leiagnostidae. Howell recently (1935a, b) has gone a step further and has split the smooth Ordovician forms as Leiagnostidae and has recognised two families of Cambrian forms with smooth shields—Phalacromidae Corda and Platagnostidae Howell.

In the Middle Cambrian there arises a group of several genera of agnostids in which the features of the dorsal shield tend to be smoothed out. The group may be polyphyletic, the same tendency being repeated in several offshoots from Agnostidae. But, if it is polyphyletic that remains to be proved. Until such proof is available I prefer to retain the genera in the one family. Therefore I include in Phalacromidae *Cotalagnostus*, in which the tendency is incipient and mainly has affected the head, *Lejopyge* and *Platagnostus*, in which it has gone a stage further and only traces of lateral grooves bounding the axial structures remain, and *Phalacroma*²⁹ in which the trend has reached its acme. Possibly the tendency is polyphyletic and orthogenetic, and the Ordovician forms, indistinguishable from *Phalacroma*, may have to be removed from that genus and grouped in *Leiagnostus* as Howell has suggested. But, although in Europe, North America and Australia no smooth forms have been recorded in the Upper Cambrian to bridge the gap between the Middle Cambrian and Ordovician groups, there are smooth agnostids of this type in the Upper Cambrian of South America (Kayser, 1897 and Hoek, 1912). Therefore, until more is learnt of the range of such forms, I think it unnecessary to recognise two family groupings.

Genus **COTALAGNOSTUS** gen. nov.

Genotype: *Agnostus lens* Grönwall 1902.

Diagnosis.—A Middle Cambrian group of agnostids with smooth cephalic cheeks and with the anterior elements of the glabella very faint or absent. Usually the posterior lobe of the glabella is defined by two subparallel furrows fading out

²⁹ As noted below I regard *Grandagnostus* and *Gallagnostus* as synonyms of *Phalacroma*.

anteriorly; though in some forms the outline of the anterior lobe may still be discerned. The accessory lobes are small. The pygidium has smooth cheeks and a non-spinose brim. The pygidial axis is trilobed, not extending posteriorly to the brim.

Notes.—In the genus may be placed *A. lens* Grönwall (1902, p. 65, pl. 1, figs. 8, 9), *A. frontosa* Grönwall (1902, p. 66, pl. 1, fig. 10), *A. altus* Grönwall (1902, p. 58, pl. 1, figs. 3, 4), *A. barrandei* Salter (see Lake 1906, p. 13, pl. 2, fig. 2) and *A. kushanensis* Walcott (1913, p. 101, pl. 7, fig. 7). In such an assemblage there is a gradation from forms with furrows strongly impressed and with prominent vestiges of the anterior lobe of the glabella (*C. frontosa*) to forms with very faint furrows and no trace of the anterior lobe (*C. altus*).

COTALAGNOSTUS aff. **KUSHANENSIS** (Walcott).

(Pl. IX, fig. 16.)

One Queensland specimen, an isolated cephalon, has the furrows impressed to about the same degree as *C. kushanensis*. As in that species the features of the anterior lobe can be distinguished with difficulty. A small tubercle is present on the posterior glabellar lobe.

The Queensland form is more elongate than *C. kushanensis* and has the tubercle a little more to the rear.

Locality and horizon.—*Dinesus* Stage of Yelvertoft Station. The specimen is in the collection of the University of Queensland.

Genus **PHOIDAGNOSTUS** gen. nov.

Genotype: *Phoidagnostus limbatus* sp. nov.

Diagnosis.—Smooth agnostids that differ from *Phalacroma* in retaining the accessory lobes of the glabella.

PHOIDAGNOSTUS LIMBATUS sp. nov.

(Pl. IX, figs. 10, 11.)

Diagnosis.—Cephalon smooth, subcircular with a narrow rim of variable width. At the base are two tubercles in the position of the accessory lobes of the glabella. No other glabellar structures are retained.

There are two segments in the thorax, the axis being smooth and inflated and the pleura also convex.

The pygidium is not known with certainty.

Remarks.—The only other species that may be included in *Phoidagnostus* is *Agnostus bituberculatus* Angelin (1851, p. 6, pl. 6, fig. 2). Angelin's figure shows no rim to the cephalon but a rim is mentioned in the description. Angelin's specimens

appear to be lost. Westergaard (in Holm and Westergaard 1920, p. 11) figured topotypes and also other forms of the species from Bennett Island. None of these have rims and Westergaard concludes that Angelin made a mistake in his description. The Queensland forms have definite rims and thus I have placed them in a separate species. It should be noted, however, that there is some variation in this feature. The two specimens that now are figured have rims of different widths. It is possible that the forms from Bennett Island are also specifically distinct since the only specimen figured by Holm and Westergaard is longer than the types of *P. bituberculatus*.

It may be that the pygidia that tentatively I have associated with *Phalacroma dubium* may really belong to this species. In the absence of complete specimens this cannot be decided; for the two species occur together and the only generic difference is in the cephalon.

Holm and Westergaard (1930, pp. 6, 11) have pointed out that *Agnostus bituberculatus* as pictured by Brögger differs from Angelin's species and they separate it as *Ag. confusus*. Actually it is generally distinct and is referable to *Lejopyge*.

Locality and horizon.—The *Phoidagnostus* Stage eight miles north-east of Duchess (University of Queensland Collections).

Genus **PHALACROMA** Corda 1847.

Genotype: *Phalacroma scutiforme* Corda 1847.

There is some confusion about the genotype of *Phalacroma*. Unfortunately I have not had access to Corda's work. Vogdes (1893) has summarised the paper and lists twelve species that Corda placed in *Phalacroma*. One of these is *P. nudum* Corda. Corda would appear to have consulted Beyrich's work on the Bohemian trilobites, published two years previously, in which *Battus nudus* Beyrich, a typical *Phalacroma*, is described. I have no means of deciding whether *Phalacroma nudum* Corda was intended to be the same as *Battus nudus* Beyrich. Howell (1935b, p. 227) quotes as genotype *Phalacroma nudum* without stating the name of the author of the species. Later in that year Kobayashi (1935b, p. 97) took *Phalacroma scutiforme* Corda as the genotype. Since, so far as I can discover, this was the only species of *Phalacroma* figured by Corda I have followed Kobayashi in this usage. Unfortunately in Vogdes' valuable list of trilobite genera (Vogdes 1925, p. 109), which was published after his death, a mistake has been made and the genotype of *Phalacroma* is stated to be *Calymene pulchra* Barrande, which is the genotype of *Pharastoma* Corda. Lake (1906, p. 15) and Illing (1916, p. 415) regard many of Corda's species of *Phalacroma*, including *P. nudum* and *P. scutiforme* as conspecific and identical with *Battus nudus* Beyrich. Should that be so (I am not in a position to decide) the genotype would be *P. nudum* (Beyrich).

In 1909 Jaekel, overlooking Corda's work, proposed the name *Leiagnostus* for such smooth forms. He included in the genus species from the Middle Cambrian and the Ordovician and selected as genotype the Ordovician *L. erraticus* Jaekel. Howell (1935a) has proposed to recognise both names—*Phalacroma* for the Middle Cambrian species and *Leiagnostus* for those from the Ordovician.

Howell (1935a and b) has proposed two new generic names within Phalacromidae—*Grandagnostus* and *Gallagnostus*. The first-named differs from typical *Phalacroma* merely in being larger, and Howell states that there are intermediate forms. Size seems to me to be a poor criterion, so that I am using the name *Phalacroma* to cover also the forms that Howell placed in *Grandagnostus*. *Gallagnostus*, too, is poorly characterised. The cephalic brim is as wide as that of the pygidium; but so it is in some species of *Phalacroma* (*P. thōrali* Howell). The pygidial brim is continuous anteriorly; but this too is seen in species of *Phalacroma* (*P. ovalis* Illing sp.). I see no reason for recording *Gallagnostus* as a separate genus unless perhaps that the thoracic segments are simpler. But these are so rarely seen that it would be an inconvenient distinction.

PHALACROMA (?) DUBIUM sp. nov.

(Pl. IX, figs. 13-15.)

Diagnosis.—Cephalon regularly oval, prominently and regularly inflated. Surrounding it is a very narrow concave brim that grades gradually into the central part of the cephalon and is visible only in very well-preserved specimens. The posterior portion of the cephalon is truncated; and on this portion there are faint markings akin to the outlines of the accessory lobes on *Phoidagnostus*.

The associated pygidium that tentatively is identified as belonging to this species is inflated, regularly oval, the brim increasing regularly in width from the antero-lateral angles towards the posterior. The brim is separated from the central portion of the pygidium by a groove, but it retains the general slope of the shield. This brim is not continued on the anterior margin. There is no median tubercle. Some forms show a pair of faint longitudinal grooves, limited to the anterior region, in the position of the anterior portion of the grooves of *Lejopyge*.

Remarks.—This remarkable species while generally becoming smooth as in *Phalacroma* retains faint grooves in the positions of those of *Lejopyge* and *Phoidagnostus*. It appears to be a generalised form that is difficult to place generically. I know of no other species that has these features. I think at present it is best placed in *Phalacroma*.

Among the phalacromids there is a group in which the pygidial brim, although prominent, is not flattened but retains some of the curvature of the rest of the shield and increases in width towards the posterior. In this group belong *P. nudum* Beyrich

sp. (1845, p. 46, fig. 20), *P. scanicum* Tullberg sp. (1880, pl. 2, fig. 18), *P. marginatum* Brögger sp.³⁰ and *P. ovale* Illing sp. (1915, p. 415, pl. 31, figs. 9, 10). Each of these forms, which have been recorded as varieties of *P. nudum* (Beyrich), bears a median tubercle on the pygidium although often this tubercle is faint. In general, apart from the faint grooves on the shields, *P. dubium* resembles this group. By its shape it may be distinguished from the other species. Also, although there seems to be a slight change in the curvature of the pygidium at the place where the tubercle normally is found, no tubercle is present. The Siberian *P. schmidtii* von Toll sp. (1896, p. 5, pl. 1, figs. 5, 12, 13, 21-23) has no median tubercle and perhaps is the closest form but in that species the cephalon is subcircular. Another somewhat similar form is *P. thoralii* Howell (1935b, p. 227, pl. 22, figs. 19, 20) which is somewhat nearer in shape. The Welsh *P. eskridgei* Hicks sp. (see Lake, 1906, p. 16, pl. 2, fig. 6) also has no tubercle; but it is a circular form with a very distinctive pygidial brim. Neither of the forms from the Upper Cambrian of South America *P. boliviensis* Hoek sp. (1912), and *P. iruyensis* Kayser sp. (1897), is particularly similar.

Locality and horizon.—The *Phoidagnostus* Stage eight miles north-east of Duchess. The holotype is in the collections of the University of Queensland. There are many other specimens in this collection as well as in the Geological Survey of Queensland.

PHALACROMA SP.

A single cephalon has been found in the beds of the *Anomocare* Stage, 52 miles from Camooweal, on the road from Camooweal to Thornton Station (University of Queensland Collection).

Genus **LEJOPYGE** Corda 1847.

Genotype: *Battus laevigatus* Dalman 1828.

LEJOPYGE EXILIS sp. nov.

(Pl. IX, figs. 9 and 12.)

Diagnosis.—Cephalon polished, subcircular, narrowing slightly towards the front and surrounded by a narrow rim. The posterior portion is subtruncate and bears two faint furrows that, starting from the posterior margin, are convergent but disappear before they have covered one-quarter the length of the shield.

The pygidium tentatively associated with the species has a broader rim than the cephalon. The axis is represented by a slight anterior projection; and posteriorly from this it is defined, until about the middle region of the pygidium, by faint converging grooves. The cheeks of the pygidium are smooth subtending an obtuse angle in the anterior portion so that the rim extends around the antero-lateral regions.

³⁰ I have not seen Brögger's paper. My information is given by Tullberg's Figure (1880, pl. 2, fig. 19).

Remarks.—The cephalon referred to this species are similar in shape to those of *Phoidagnostus limbatus* and there is a tendency to confuse the two forms. The fact that some specimens have accessory lobes and some only posterior circum-glabellar furrows indicates that the two groups, similar in outline, should be separated. Several pygidia with typical, faint, circum-axial furrows confirm the presence of *Lejopyge*.

The species is more faintly furrowed than the genotype *L. laevigatus* (Dalman). Perhaps the closest form is the Norwegian *L. confusus* Holm and Westergaard sp. (1930, p. 12, pl. 4, figs. 7, 8). That species, however, has a shorter cephalon. *L. lenaicus* von Toll sp. (1896, p. 23, pl. 1, figs. 6-8, 10, 11, 14-17, 24) from Siberia has more elevated axes. The Welsh *L. barlowi* Belt sp. (see Lake 1906, p. 16, pl. 2, fig. 7) differs in the anterior features of the pygidium and in the greater persistence of the cephalic grooves. The Newfoundland species (*terranovica* and *ciceroides*) that Matthew (1896b) recorded as varieties of *Agnostus laevigatus* are probably closer to *Cotalagnostus* than *Lejopyge*.

Locality and horizon.—*Phoidagnostus* Stage eight miles north-east of Duchess (University of Queensland Collection).

Family PSEUDAGNOSTIDAE fam. nov.

I am grouping in the one family the three genera *Pseudagnostus* Jaekel (1909), *Plethagnostus* Clark (1923) and RHAPTAGNOSTUS gen. nov. This last named genus, for which *Agnostus cyclopygeformis* Sun (1924, p. 26, pl. 2, fig. 1) is selected as genotype, is very similar to *Pseudagnostus*, differing from it only in having on the pygidium an elliptical arrangement of foramina in the post-axial region, and a simple, non-spinose brim.

In *Pseudagnostus* and *Rhaptagnostus* the cephalon is of the *Agnostus* type, with an added pair of more or less prominent, discontinuous furrows in the anterior portion of the posterior glabellar lobe. There is a tendency in these forms for all furrows on the head to become indistinct. The pygidium has two axial lobes, but the furrow dividing them is usually faint and it often appears that only the one lobe is present. Occasionally, as in *Pseudagnostus orientalis* Kobayashi (1933, p. 98, pl. 9, figs. 20-22), the faint outline of the third (posterior) lobe, in the normal *Agnostus* position may be seen. The unique foraminal line of *Rhaptagnostus*, which occupies this position, thus appears to be homologous with the circum-axial furrow of the third lobe. From the postero-lateral angles of the second pygidial lobe a pair of furrows extends to or towards the brim at the mid points of the sides.

There is a most interesting homoeomorph of this family in "*Agnostus*" *securiger* Lake (1906, p. 20, pl. 2, fig. 11), which also has a pair of furrows extending from the postero-lateral angles of the second pygidial lobe to the middle points of the

sides of the brim. This species, as Lake has pointed out, is very similar in most features to *Peronopsis integer* Beyrich sp. (cf. Lake pl. 2, fig. 10) and it is clear from this relationship that the portion of the pygidium contained within the posterior furrows is merely the third lobe expanded to fill the whole posterior portion of the pygidium. That is, the furrows on "*Agnostus*" *securiger* are the ordinary circum-axial furrows of the posterior lobe, whereas in *Pseudagnostus* they form a separate feature with no recorded homologue so far as I am aware in any other agnostid.

In 1933 Kobayashi (p. 97, pl. 9, figs. 19, 23, 24 ; pl. 10, fig. 7) figured a Korean form as *Pseudagnostus cyclopygeformis* Sun. This differs from the Chinese species, as Sun (1935, p. 16) has pointed out. It has a simple pygidial brim but no foramina, and so would appear more likely to belong to *Plethagnostus*. In 1935 Kobayashi described another species, this time from Alaska, as *Pseudagnostus* (*Plethagnostus*) *clarki* Kob. This too has a simple brim. Both *P. cyclopygeformis* Kobayashi non Sun and *P. clarki* Kob. have the peculiar type of glabella in which, by the interaction of lateral and transverse furrows, there are subsidiary lobes on the front of the posterior lateral lobe. When Clark (1923, p. 124) erected the genus *Plethagnostus* he referred to it merely the genotype, *P. gyps* Clark, that was stated to be known only from the pygidium. But with this pygidium, in the Upper Cambrian boulders at Levis, Quebec, was a cephalon with the same cephalic features that are shared by Kobayashi's two species. Clark referred this to *Agnostus americanus* Billings, reproducing for comparison Billings' figures. The association of similar specialised cephalae and pygidia in three widely separated regions (Quebec, Alaska and Korea) suggest that the cephalon of *Agnostus americanus* does not belong to the pygidium that Billings figured with it, but belongs to *Plethagnostus*. It should be noted that this type of cephalon is not peculiar to *Plethagnostus* but is borne also by *Pseudagnostus* (see for example the figure given by Westergaard 1922, pl. 1, figs. 7, 8). However, in some forms (*e.g.* *P. douvillei* Bergeron sp. and the Australian forms now recorded) the additional lobes on the glabella become very faint or disappear.

In each country, Canada, Alaska, and Korea, *Plethagnostus* is found in beds high in the Upper Cambrian, and is consistently later in age than *Pseudagnostus* and *Rhaptagnostus*.

Thus I suggest that the shields of the genera of Pseudagnostidae are differenced as follows. Each has the family characteristics of a cephalon with *Agnostus*-like furrows and, often, a third pair of glabellar furrows. These cephalic furrows frequently become very faint. The pygidium tending to become smooth has no third (posterior) lobe but has instead a pair of adventitious pleural furrows extending outwards from the postero-lateral corners of the second lobe. To these features *Pseudagnostus* adds a pair of pygidial spines. *Rhaptagnostus* which should be regarded

as a specialised offshoot, has the curious foraminal ellipse, while *Plethagnostus* retains a non-spinose pygidial rim. The continuous nature of the pleural furrows in *P. gyps* which was the feature on which Clark based his genus *Plethagnostus*, is regarded as but of specific value. *P. gyps*, with its strong furrows is at one extreme of *Plethagnostus*. At the other extreme is the relatively smooth *P. clarki* Kobayashi in which even the pre-glabellar furrow has disappeared.

Pseudagnostus is the earliest of the three genera, being found in the lowest parts of the Croixian (early Upper Cambrian). The Australian *P. vastulus* is found even as low as the top of the Middle Cambrian. *Rhaptagnostus*, known only in China, is on a rather higher level (*Kaolishania* Beds) while *Plethagnostus* is later still, being found in the uppermost Croixian of Korea (*Tsinania* Beds) and Alaska (*Parabriscoia* Beds) and in the Tremadocian (Ozarkian) of Quebec.

Pseudagnostidae is regarded as derived from Agnostidae by the suppression of a posterior pygidial lobe and the development instead of adventitious pleural furrows.

Genus **PSEUDAGNOSTUS** Jaekel 1909.

Genotype: *Agnostus cyclopyge* Tullberg 1880.

PSEUDAGNOSTUS VASTULUS sp. nov.

(Pl. X, figs. 3, 4.)

Diagnosis.—Cephalon slightly longer than broad with a regularly arcuate margin. The rim is strongly marked off from the rest of the head and is relatively broad, declining at the postero-lateral angles. The glabella has subparallel sides and is defined by a well-impressed circum-glabellar furrow. The anterior and posterior lobes are divided by a distinct groove. There is a very slight contraction of the posterior glabellar lobe at the rear of the anterior third. Opposite this is a small elongate, median tubercle. The cheeks are inflated. The pre-glabellar furrow is only faintly impressed. The accessory lobes are small and sub-equilateral.

The pygidium has approximately the same outline as the cephalon. It is regularly arched and the grooves upon it are more faintly impressed than on the head. The anterior grooves are slightly convergent posteriorly. The transverse connecting furrow is faint and has a slight curvature convex to the posterior. The lateral grooves are fainter still. Towards the rear of the anterior lobe (really the second lobe) there is an elongated tubercle through it is not very prominent. The rim is relatively flat and (as seen in a young specimen) bears small postero-lateral spines.

Remarks.—This is a relatively large species. The most similar form is the Chinese *P. douvillei* Bergeron sp.³¹ which has a wider pygidial rim but otherwise agrees

³¹ See particularly Monke (1902), p. 111, pl. 3, figs. 1-9, where it is recorded as *Agnostus koeferi*, and Walcott (1913) p. 100, pl. 17, figs. 3 and 8.

very well with *P. vastulus*. Most of the other species of *Pseudagnostus* in Europe and Asia, e.g. *P. cyclopyge* (Tullberg) and *P. orientalis* (Kobayashi), are easily distinguished by the more prominent second glabellar furrow although one form figured by Lake (1906, pl. 2, fig. 21) is similar to *P. vastulus* in this feature. However it is otherwise quite distinct.

Locality and horizon.—The species is abundant in the *Anorina* Stage, 4 miles north of the Twenty Mile Bore on Glenormiston (University of Queensland Collection). Two specimens have been found in the *Solenopleura* Stage of Chatsworth homestead (University of Queensland Collection).

PSEUDAGNOSTUS NUPERUS sp. nov.

(Pl. X, figs. 5-7.)

Diagnosis.—Cephalon subcircular with a prominent rim that, while distinct, is not separated by a furrow. The glabella is large, relatively narrow, and has subparallel sides. The anterior glabellar furrow is faint; and there is, behind it, a very faint pair of depressions that represent the second furrow. The median tubercle is very long but very indistinct. The accessory lobes are relatively prominent and sub-equilateral. There is a pre-glabellar furrow that in some specimens is fairly well impressed and in others is hardly noticeable.

The pygidium has a very regular, subcircular outline and the marginal spines are very small. The rim is wide with a sulcus succeeded by a slightly raised edge. The axial and postero-lateral furrows are very faint and the pygidial tubercle is small.

Remarks.—The closest forms would seem to be *P. vastulus* and *P. douvillei* but they differ slightly in shape and, in addition, have a more robust glabella. Some comparison, particularly in glabellar features, may be made with *P. primus* Kobayashi (1935b, p. 108, pl. 14, figs. 6-10) although the two species differ considerably in outline.

On plate X two glabellae and a pygidium are figured. One glabella (fig. 7) is more inflated and has less strongly impressed grooves than the other (fig. 6); but they agree in other features and for the present I group them together.

Locality and horizon.—The *Elathriella* Stage at the base of the hill immediately west of Tyson's Bore on Glenormiston (University of Queensland Collection).

PSEUDAGNOSTUS cf. **CYCLOPYGE** (Tullberg).

(Pl. X, fig. 8.)

From the *Glyptagnostus* Stage 16 miles south of Glenormiston homestead a few tails of *Pseudagnostus* have been collected. These agree in general features with the genotype, *P. cyclopyge* Tullberg sp. (1880, p. 26, pl. 2, fig. 15), particularly the form figured by Westergaard (1922, pl. 1, fig. 8). They are in the collection of the University of Queensland.

Family GLYPTAGNOSTIDAE fam. nov.

It is proposed to include in this family the Upper Cambrian forms in which the pygidial axis is laterally trifold throughout its length. The glabella has well-defined anterior and posterior lobes and a pre-glabellar furrow is present.

Two genera may be placed in the family. *Glyptagnostus* gen. nov. is defined below. LOTAGNOSTUS, gen. nov. is proposed for the group of *Agnostus trisectus* Salter (1864, p. 10, pl. 1, fig. 11), a specimen figured by Westergaard (1922, pl. 1, fig. 12) being taken as the genoholotype. In this genus the glabella which is smooth has prominent anterior and posterior lobes and the accessory lobes are large. The pygidium has a pair of marginal spines. The pygidial axis has a chequered appearance due to the prominent trifold division both longitudinally and laterally. The cheeks of both cephalon and pygidium have radial and sub-reticulate ornament.

Glyptagnostus is more ornate and has a longitudinal furrow of varying prominence in the anterior glabellar lobe.

In each genus there is a tendency to develop a pair of medio-lateral depressions on the posterior glabellar lobe.

It is possible that the family Glyptagnostidae, beginning in the earlier portion of the Upper Cambrian, is derived from the Middle Cambrian Diplagnostidae. *Glyptagnostus*, the earlier of the two genera in this new family, has a median furrow or depression in the anterior lobe of the glabella, similar to that found in the members of Diplagnostidae. In the earlier family some forms of *Tomagnostus*, for example *T. perrugata* Grönwall sp. (1902, p. 50, pl. 1, fig. 1), foreshadow the typical ornament of the later group, while in some forms of *Enetagnostus*, *E. arcticus* Holm and Westergaard sp. (1930, pl. 1, figs. 26-30) for instance, the prominent, elongate tubercle of the pygidial axis suggests that the laterally trifold axis of the pygidium of Glyptagnostidae may have developed by the exaggeration of just such a feature.

Genus GLYPTAGNOSTUS gen. nov.

Genotype: *Glyptagnostus toreuma* sp. nov.

Diagnosis.—Cheeks of the cephalon and pygidium richly ornamented with reticulate furrows that pass laterally into radial ornament. Glabella narrow, with parallel or subparallel sides, and with the anterior lobe marked by a median, longitudinal furrow or depression. Accessory lobes small, possibly multiple. Pygidial axis transversely divided into four lobes, and divided also by furrows into three longitudinal zones. The two outer of these zones may be further subdivided. A pair of marginal spines is present on the pygidium.

Remarks.—When Jaekel (1909) erected the genus *Ptychagnostus* he based his description on the genotype, the ornate *Agnostus punctuosus* Angelin, but included within the genus other ornamented forms that did not agree in all their features with

the generic diagnosis. The groups of *Ag. trisectus* Salter (*Lotagnostus*) and *Ag. reticulatus* Angelin (*Glyptagnostus*) are now removed from this assemblage and *Ptychagnostus* is restricted to forms, like the genotype, that have divided accessory lobes on the cephalon, normal, trilobed pygidial axes but no post-axial furrow on the pygidium. These forms agree also in having incipient lateral furrows on the posterior lobe of the glabella. *Ptychagnostus* in its restricted sense is thus very close to *Triplagnostus* Howell.

In so many groups of the agnostids radial ornament is developed that it is untenable to gather into one genus all the ornate forms. *Glyptagnostus* has the most highly ornamented surface among the agnostids; but even its striking, reticulate furrows clearly have arisen from the common and recurrent radial ornament. Radial grooving, arising sporadically in independent groups, often is restricted to the cephalon. Usually these radial furrows are alternately long and short. Even in the most reticulate forms of *Glyptagnostus* there is clear trace, in the marginal areas, of radial structure based on alternating long and short furrows.

GLYPTAGNOSTUS TOREUMA sp. nov.

(Pl. IX, figs. 17-20.)

Diagnosis.—Cephalon elliptical, length slightly greater than the breadth. The glabella is narrow with subparallel sides. The anterior lobe is separated by a prominent groove that centrally has an embayment concave posteriorly; this lobe is divided by a shallow longitudinal furrow. The posterior lobe has a long but not prominent tubercle and is slightly contracted about the rear of the anterior third. Adjacent to the posterior lobe of the glabella there are lobes that may be multiple accessory glabellar lobes or else more prominent reticulation of the pleura. The pleura are of uniform width and bear, adjacent to the glabella, a series of coarse, nodose prominences due to the reticulation of the surface. A pair of such prominences extends outwards from the anterior end of the glabella, leaving in between a shallow groove that may represent the normal pre-glabellar furrow. Towards the margin the reticulations pass into regular, radial grooves, connected by secondary grooves normal to their length, while finally, immediately beside the rim, the radial ornament is resolved into alternate long and short furrows. The rim is narrow and flat.

The pygidium has a wide, long, acutely triangular axis extending almost to the rim and succeeded by a post-axial furrow. The axis has three primary lobes. The anterior axial lobe marginally bears four secondary lobes. The median axial lobe is laterally trifid (continuing the marginal division of the anterior lobe); anteriorly it bears a pair of large secondary lobes succeeded posteriorly by a flattened zone faintly subdivided into elongate sections. The posterior axial lobe is lanceolate and simple. The centre of the entire axis is raised into a type of long tubercle. The pleura have

coarse nodose prominences definitely arranged in radial series, the radii becoming alternately long and short near the margin. Each radial sector has the nodose prominences, roughly equidimensional, increasing in size towards the axis. There are about 7 primary radial sectors on each side. The rim is narrow, slightly convex and bears a pair of short spines pressed towards the margin.

Remarks.—Hitherto all members of this genus, which was known only from Europe, have been included under the name *Agnostus reticulatus* Angelin. Unfortunately many of the figures given are sketchy and do not show the full detail of the ornament. This applies particularly to the figures given by Angelin (1851), Tullberg (1880) and Gürich (1908). Also there has been disagreement among European workers on the variation of their forms. The type came from Sweden. Brögger (1882, p. 57), recording the species from Norway, stated that the Norwegian and Swedish forms differ. Lake (1906, p. 8) also notes differences in the Welsh form. However lately Westergaard (1922, p. 117), taking apparently a conservative attitude, has stated that there are no differences between these three forms. The figure that he gives, from Angelin's locality, is probably the best that yet has appeared.

I have been perplexed whether the Queensland form should be recorded as *G. reticulatus*. However all the Queensland specimens have in common certain features of the ornament that show slight differences from the Swedish form as figured by Westergaard. For instance the reticuli near the cephalon are coarser and the lateral lobes of the pygidial axis are not so minutely subdivided. For that reason I prefer to record this as a separate species.

Locality and horizon.—Very abundant in beds from 14 to 16 miles south of Glenormiston in the *Glyptagnostus* Stage (University of Queensland and Geological Survey of Queensland Collections).

? Family TRINODIDAE Howell 1935b.

It is possible that Trinodidae Howell is synonymous with Metagnostidae Jaekel. Kobayashi (1935b, p. 98) has shown that *Metagnostus* Jaekel 1909 is synonymous with *Arthrorachis* Corda 1847. Thus the name Metagnostidae must be abandoned. *Hypagnostus* is tentatively placed in the family Trinodidae.

Genus **HYPAGNOSTUS** Jaekel 1909.

Genotype: *Agnostus parvifrons* Linnarsson.

HYPAGNOSTUS VORTEX sp. nov.

(Pl. IX, figs. 7, 8.)

Diagnosis.—Cephalon subquadrate in outline, rather broader than long. Glabella, as is usual for the genus, restricted to the posterior and accessory lobes that are outlined by rather broad furrows. Posterior glabellar lobe regularly oval. This

lobe is about one-half the length of the parial portion of the cephalon and one-third the width. Accessory lobes not very distinct although relatively large.

The pygidium is subquadrate to semicircular in outline. The pygidial axis extends to the brim, separating the cheeks. The brim is prominent and without spines.

Notes.—A cephalon and a pygidium, isolated from one another, are preserved on a piece of chert with *Triplagnostus atavus* (Tullberg). No other specimens are known. In each the axial region is slightly abraded.

Hypagnostus includes a number of Middle Cambrian species, some of which are incompletely known. The genotype, *H. parvifrons* Linnarsson sp.³² is perhaps the form most similar to *H. vortex* each species having the pygidial axis completely parting the cheeks. Of the two *H. vortex* has the more quadrate outline. The Chinese *H. latelimbatus* Lorenz sp. (1906, p. 84, pl. 4, fig. 9; pl. 5, figs. 10, 11) has a shorter axis, but the cheeks are divided by a post-axial furrow. *H. brevifrons* Angelin sp. (see Tullberg 1880, pl. 2, fig. 29) has a similar short axis but no post-axial furrow. *H. repandus* Holm and Westergaard sp. (1903, p. 13, pl. 1, figs. 35-43; pl. 4, figs. 11, 12) of which the pygidium is unknown is sharply differentiated by its peculiar, acuminate glabella. Other unnamed species have been figured by the latter authors (*ibid.*, pl. 1, figs. 3, 4) but these, known only from cephalae, are rather different in shape from *H. vortex*. *H. exsculptus* (Angelin) and its variety *didymus* (Wallerius 1930, p. 58) have shorter pygidial axes. *H. umbo* Matthew sp. (1896, p. 173, pl. 1, fig. 6) from Newfoundland differs in the proportions of the cephalic features and the shape of the pygidium.

Horizon and locality.—The holotype and paratype are contained on the one specimen in the collection of the University of Queensland. This comes from the *Dinesus* Stage of Yelvertoft Station.

Family Uncertain.

Genus **ASPIDAGNOSTUS** gen. nov.

Genotype: *Aspidagnostus parmatius* sp. nov.

Diagnosis.—Cephalon subcircular, contracted posteriorly. Glabella undivided, diverging anteriorly, extending about half the length of the cephalon and rounded anteriorly. A prominent, straight, longitudinal furrow divides the pre-glabellar field. The associated pygidium has a wide axis that diverges posteriorly and extends to the posterior margin. It bears two pairs of discontinuous furrows.

³² The figures given by Tullberg (1880, pl. 2, figs. 26-28) may represent more than one species.

ASPIDAGNOSTUS PARMATUS sp. nov.

(Pl. IX, figs. 5, 6.)

Diagnosis.—Individuals small. Cephalon subcircular, widest in the median region. The glabella is contracted at the base and rounded anteriorly. The centre portion of the glabella is raised in the manner of a large, somewhat imperfectly defined tubercle that reaches to the posterior margin but otherwise is concentric with the glabella. There are no grooves on the glabella and no accessory lobes. A straight, longitudinal furrow divides the pre-glabella field which is nearly one half the length of the shield. The cheeks are traversed by irregular, radial furrows. The rim is narrow and of uniform width.

The one pygidium associated with the glabella is contracted slightly anteriorly, the widest part being about the base of the anterior third of the shield. The axis is large, occupying about two-thirds of the pygidium. Two pairs of discontinuous, transverse furrows are present, widely spaced, dividing the axis into three subequal portions. The axis is sack-shaped, widening posteriorly, and extending to the posterior margin of the cheeks. The rim of the pygidium is slightly wider than that of the cephalon.

I know of no other species that can be placed in *Aspidagnostus*.

Locality and horizon.—From the *Elathriella* Stage at the base of the hill immediately west of Tyson's Bore on Glenormiston Station (University of Queensland Collection), three heads and one tail have been collected.

GEN. ET SP. INDET.

(Pl. X, fig. 9.)

From the *Elathriella* Stage at the base of the hill immediately west of Tyson's Bore on Glenormiston I have obtained small cephalons that are very inflated but their surface features are not sufficiently well preserved for the form to be placed. The pygidium described by Walcott and Resser (1924, p. 5, pl. 1, fig. 3) as *Aagnostus septentrionalis* from the Ozarkian of Novaya Zemlya has certain similar features although it is a wider type. The specimens are in the collection of the University of Queensland.

NEW GENERIC NAMES.

The names of new genera of trilobites proposed in this paper are set out below, each with its genotype.

ANORINA—*Liostracus* (?) *superstes* Linnarsson.

ASPIDAGNOSTUS—*Aspidagnostus parmatum* sp. nov.

COTALAGNOSTUS—*Aagnostus lens* Grönwall.

ENETAGNOSTUS—*Enetagnostus humilis* sp. nov.

EUAGNOSTUS—*Euagnostus opimus* sp. nov.

GLYPTAGNOSTUS—*Glyptagnostus toreuma* sp. nov.

HEBEDISCUS—*Ptychoparia* (?) *attleborensis* Shaler and Foerste.

LOTAGNOSTUS—*Agnostus trisectus* Salter (genoholotype figured by Westergaard).

ONCAGNOSTUS—*Agnostus hoi* Sun.

PHOIDAGNOSTUS—*Phoidagnostus limbatus* sp. nov.

RHAPTAGNOSTUS—*Agnostus cyclopygeformis* Sun.

SOLEAGNOSTUS—*Agnostus longifrons* Nicholas.

XYSTRIDURA—*Olenellus browni* Etheridge fil.

ACKNOWLEDGMENTS.

I wish to record a debt of gratitude that I owe to Mr. C. Ogilvie, B.E., of the Department of Irrigation and Water Supply, Brisbane. The recognition of the Georgina Limestones as a Series is due to him. He made the first collections from these beds; and his subsequent collections, that he has presented to the University of Queensland, have been invaluable in this work. To the owners and managers of several of the far western stations I am grateful for extended hospitality when engaged in field investigations. I would mention particularly Mr. E. H. Hamilton (late of Glenormiston) and Mr. N. Marlay (of Warendra). To several of my companions on these excursions, notably Mr. C. Ogilvie, Mr. Graham Hall and Mr. R. Galt, I am indebted for considerable help. I would pay a tribute, also, to the memory of Sir Edgeworth David. His valuable discussions of this work, while it was in progress, I much appreciated.

I place on record also my indebtedness to the Australian Museum (Sydney) for the loan of type material, and to the Fisher Library (University of Sydney) and the Australian Museum for the loan of literature not available in Brisbane. To Mr. H. A. Longman, Director of the Queensland Museum, I am grateful for many facilities that he placed at my disposal.

QUEENSLAND MUSEUM COLLECTIONS.

Topotypes of all species described in this paper, or plaster casts where only the one specimen is known, have been placed in the collections of the Queensland Museum.

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* My copy is the reprint of 1878.

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EXPLANATION OF PLATES.

PLATE VIII.

Figs. 1-5. *Pagetia significans* (Eth. fil.) (p. 81).

1. A complete specimen from the Templeton River, x. 8. (U.Q. Coll.).
2. A similar specimen from the same locality. (G.S.Q. Coll.).
3. A large head from the Templeton River, showing glabellar furrows and traces of palpebral ridges, x. 6. (U.Q. Coll.).
4. Lectotype of the species (the original of pl. 1, fig. 7 of Etheridge), x. 6. From 40 miles S.E. of Elkedra (A. M. Coll.).
5. Cotype (the original of plate 1, fig. 9 of Etheridge). Same locality (A. M. Coll.).

Middle Cambrian (*Dinesus* Stage).

Figs 6, 7. *Triplagnostus gibbus* (Linnarsson), x. 6 (p. 84).

A head and a tail from the Templeton River (U.Q. Coll.).

Middle Cambrian (*Dinesus* Stage).

Figs 8, 9. *Triplagnostus atavus* (Tullberg) (p. 85).

8. An immature specimen showing few furrows on the head, x. 6. Yelvertoft Station (U.Q. Coll.).

9. Mature forms, x. 8. Same locality and collection.

Middle Cambrian (*Dinesus* Stage).

Figs. 10-12. *Euagnostus opimus* gen. et sp. nov., x. 6 (p. 87).

10. A head and 11 a tail. Fig. 11 is the holotype.

12. A smaller tail.

All three specimens from the main road from Camooweal to Thornton Station, 52 miles from Camooweal (U.Q. Coll.).

Middle Cambrian (*Anomocare* Stage).

Figs. 13-16. *Solenagnostus acuminatus* gen. et sp. nov., x. 6 (p. 86).

Two heads and two tails in U.Q. Coll. 13, 15 and 16 from the *Phoidagnostus* Stage eight miles east of Duchess. 14 from the *Dinesus* Stage of Yelvertoft. Fig. 14 is the holotype.

Figs 17-19. *Enetagnostus humilis* gen. et sp. nov., x. 6 (p. 91).

Two heads and a tail from eight miles N.E. of Duchess. Fig. 18 is the holotype. (U.Q. Coll.).

Middle Cambrian (*Phoidagnostus* Stage).

PLATE IX.

(All figures x. 6.)

Figs. 1, 2. *Diplorrhina normata* sp. nov. (p. 89).

1. Holotype ; 2. A pygidium.

Dinesus Stage of the Templeton River (U.Q. Coll.).Figs. 3, 4. *Diplorrhina elkedraensis* (Eth. fil.) (p. 88).

3. Lectotype (original of plate 2, figure 1 of Etheridge).

4. Cotype (original of plate 2, figure 2 of Etheridge).

Dinesus Stage 40 miles S.E. of Elkedra (A. M. Coll.).Figs. 5, 6. *Aspidagnostus parmatus* gen. et sp. nov. (p. 105).

5. A cephalon (holotype) ; 6. A pygidium.

Elathriella Stage at the base of the hill immediately west of Tyson's Bore, Glenormiston (U.Q. Coll.).Figs. 7, 8. *Hypagnostus vortex* sp. nov. (p. 103).

7. A cephalon (holotype) ; 8. A pygidium.

Dinesus Stage of Yelvertoft (U.Q. Coll.).Figs. 9 and 12. *Lejopyge exilis* sp. nov. (p. 96).

9. A cephalon showing faintly the basal furrows (holotype).

12. A pygidium presumably belonging to this species.

Phoidagnostus Stage eight miles N.E. of Duchess (U.Q. Coll.).Figs. 10 and 11. *Phoidagnostus limbatus* gen. et sp. nov. (p. 93).

Two cephalons each with portions of the thoracic segments attached. Fig. 10 is the holotype (U.Q. Coll.).

Phoidagnostus Stage eight miles N.E. of Duchess (U.Q. Coll.).Figs. 13-15. *Phalacroma* (?) *dubium* sp. nov. (p. 95).

13. A cephalon (holotype) ; 14 and 15. Pygidia tentatively referred to the species.

Phoidagnostus Stage eight miles N.E. of Duchess (U.Q. Coll.).Fig. 16. *Cotalagnostus* aff. *kushanensis* (Walcott) (p. 93).A cephalon from the *Dinesus* Stage of Yelvertoft (U.Q. Coll.).Figs. 17-20. *Glyptagnostus toreuma* gen. et sp. nov. (p. 102).

17 and 18. Cephalons ; 19 and 20. Pygidia. 19 is the holotype. Figs. 19 and 20 (differing slightly in magnification) represent the same individual, 20 being the internal mould and 19 a plaster squeeze of the external mould.

Glyptagnostus Stage 16 miles south of Glenormiston (U.Q. Coll.).

PLATE X.

Fig. 1. *Triplagnostus gibbus* (Linnarsson) and *T. atavus* (Tullberg) (pp. 84 and 85).
Dinesus Stage of the Templeton River (U.Q. Coll.) x. 8.

Fig. 2. *Triplagnostus gibbus* (Linnarsson) x. 3 (p. 84).
A collection of individuals from the *Dinesus* Stage of the Templeton River (G.S.Q. Coll.).

Figs. 3, 4. *Pseudagnostus vastulus* sp. nov. x. 6 (p. 99).
3. A cephalon; 4. A pygidium (holotype).
Anorina Stage four miles north of Twenty Mile Bore, Glenormiston (U.Q. Coll.).

Figs. 5, 7. *Pseudagnostus nuperus* sp. nov. x. 6 (p. 100).
5. A cephalon (holotype).
6. A crushed pygidium.
7. A cephalon tentatively included in the species.
Elathriella Stage at the base of the hill immediately west of Tyson's Bore, Glenormiston (U.Q. Coll.).

Fig. 8. *Pseudagnostus* cf. *cyclopyge* (Tullberg) x. 6 (p. 100).
A pygidium from the *Glyptagnostus* Stage 16 miles south of Glenormiston (U.Q. Coll.).

Fig. 9. Gen. et sp. indet. x. 6 (p. 105).
Elathriella Stage at the base of the hill immediately west of Tyson's Bore, Glenormiston (U.Q. Coll.).